AN ABSTRACT OF THE THESIS OF

Larry Duane Bryant for the degree of Doctor of Philosophy in Rangeland Resources presented on May 7, 1993

Title: Quality of Bluebunch Wheatgrass (*Agropyron spicatum*) as a Winter Range Forage for Rocky Mountain Elk (*Cervus elaphus nelsoni*) in the Blue Mountains of Oregon

Abstract approved: Redacted for Privacy

This research was conducted on three study areas on elk winter ranges in Northeast Oregon. One was on the Starkey Experimental Forest and Range and the others were in the same vicinity. Plant appendages, spring and fall defoliation and fall growth of bluebunch wheatgrass were evaluated in terms of quality of nutrient content during September through April of 1986-87 and 1987-88. Four treatments were applied. Plants were clipped to a 2.5 cm and 7.6 cm stubble height in the spring before the boot stage of phenological development; plants were clipped to a 7.6 cm stubble height in the fall after plant maturity in September; plants were not clipped during the year. Percent crude protein, dry matter digestibility (DMD), acid detergent fiber (ADF), and lignin were evaluated monthly. Samples from the four treatments were also analyzed from October to April to determine monthly changes in nutrient contents.

Production of growth from all treatments was measured in October and March each year.

Leaf material had higher percent crude protein and DMD, with lower percent ADF and lignin than the inflorescence and culm. The third leaf (the youngest plant material) had the highest nutrient value of all appendages. The culm and inflorescence values were not statistically different.

Growth following spring defoliation treatments produced higher percent crude protein and DMD ($P<.05$), with a lower percent ADF and lignin than non-treated plants in both years. This was particularly pronounced during 1986 when precipitation in late summer initiated fall growth. Growth following spring defoliation and bluebunch wheatgrass not defoliated did not produce crude protein or DMD values sufficient to meet minimum dietary maintenance requirements for elk.

Fall precipitation adequate to promote fall growth occurred only in 1986. Growth after fall defoliation had the highest percent crude protein and DMD with the lowest ADF and lignin values of all vegetation sampled. However, without 3-5 cm of late summer/early fall rains, fall growth does not occur. This happened in 1987. When growth does occur in fall the quality of the growth exceeds the minimum dietary maintenance requirements for elk.

Freezing and thawing of fall growth plant material had minimal effect on forage quality. There were differences ($P<.05$) between the monthly values for percent crude protein and ADF starting in October and ending in April. However, the percent DMD and lignin from October to April were not different ($P<.05$).

Quality of Bluebunch Wheatgrass (Agropyron spicatum)
as a Winter Range Forage for Rocky Mountain Elk
(Cervus elaphus nelsoni)
in the Blue Mountains of Oregon

by

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INTRODUCTION

Demarcations of fall, winter, and spring ranges for big game animals in mountainous areas throughout the Intermountain West vary annually due to cold weather severity, particularly as related to accumulations of snow. Expansions of human developments are encroaching upon many of these valuable winter ranges which force the big game populations into fewer and smaller wintering areas (Sweeney and Sweeney 1984). As a result of this, forage allocation between livestock and native ungulates on both public and private lands is an increasingly significant management issue (Cooperrider 1982).

Summer ranges for elk and Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) have not traditionally been considered a limiting factor. This may be incorrect. It is unlikely forage quality and quantity during late spring (June) and early summer (July) is limiting populations of deer and elk within the Blue Mountains (Pickford and Reid 1948, Skovlin 1967). By the end of July, however, many grass species are responding to lack of sufficient moisture to continue growth (Figure 1) with senescence proceeding rapidly and quality as determined by crude protein content and dry matter digestibility deteriorating at about the same rate (Skovlin

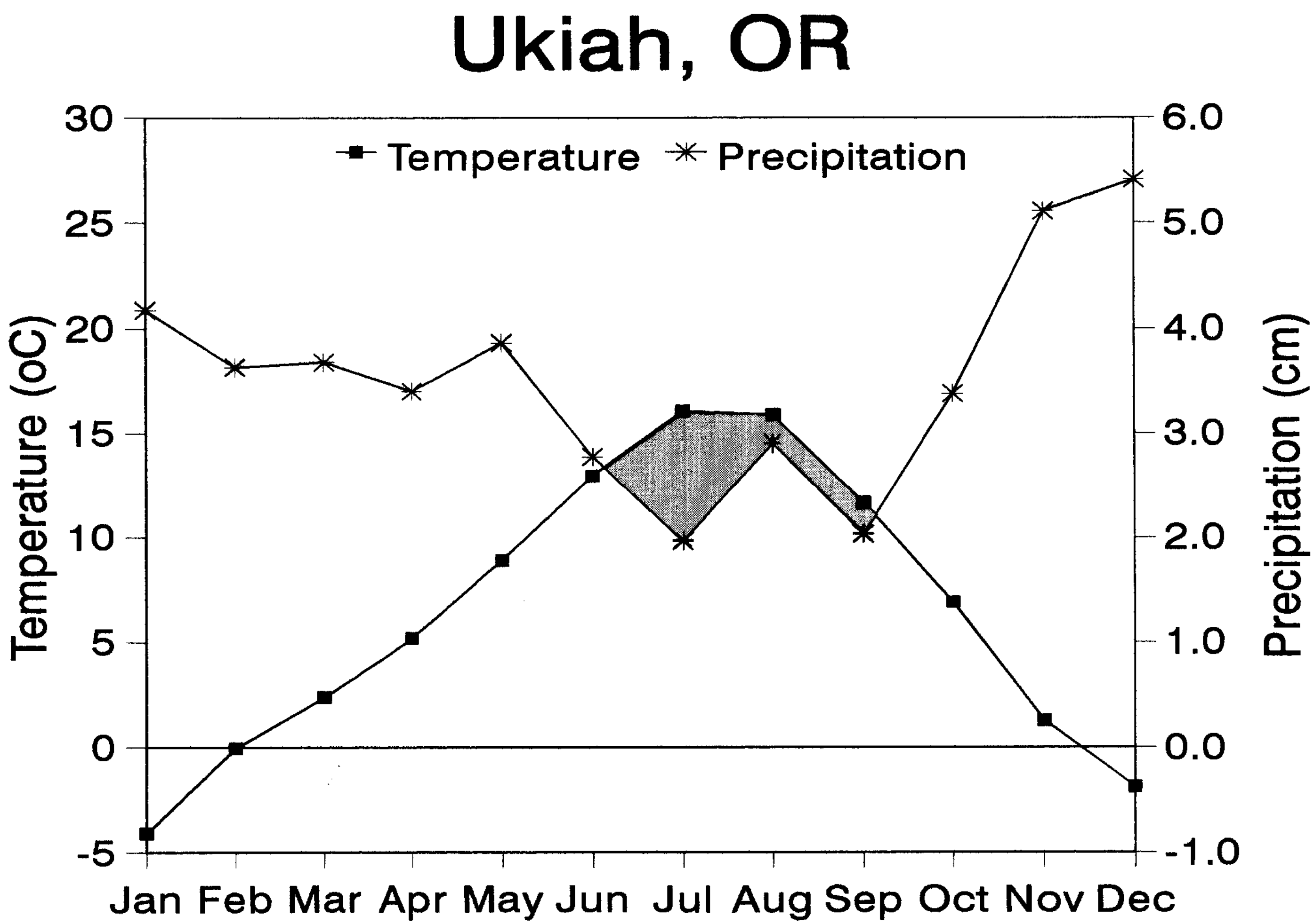

Figure 1. The Average Temperature and Precipitation Measurements from 1979-89; Illustrating the Moisture Stress Period for Plant Growth.

1967). During this time nutritional requirements of wild ruminants for maintenance, growth, lactation, antler development, and thermal regulation minimize their capabilities to accumulate fat reserves until late summer (McCorquodale 1991). Therefore, forage quality and availability in late summer (early September) and early fall (late September, early October) become the limiting factor on their capability to accumulate fat reserves. Lack of this energy reserve can adversely influence their ability to cope with inclement weather conditions during winter months, especially if snow accumulation restricts availability of quality forage (Leege and Hickey 1977).

In addition to amount and quality of forage left on summer ranges is the availability and quality of forage on fall, winter and spring ranges. The amount and quality of forage on these areas can be critical to winter survival of big game populations (Leege and Hickey 1977). Nutritional quality of fall forage influences the ability of elk to accumulate body fat reserves to withstand extended periods of negative energy balances. On winter ranges where snow accumulation often restricts forage availability and intake rates, forage quality is a paramount factor in the survival of wild ungulates (Robinette et al. 1952). Although spring ranges perhaps are not as critical to wild ungulates as fall or winter ranges, forage quality is important to those animals surviving the winter and who have depleted their body reserves (Nelson and Leege 1982, Lyon and Ward 1982). This is especially true of pregnant females who are entering the final trimester of pregnancy (Thorne et al. 1976, Moen 1973).

Competition between livestock and big game, whether actual or perceived, is a major point of contention between livestock raisers and wildlife managers. Big game reduce the quantity and quality of forage for livestock in some cases and the reverse occurs in other cases.

Obviously, some level of forage utilization and trampling by big game populations occurs (Holechek et al. 1989); the significance of this impact is assumed to be correlated with population densities and period of grazing (Putman 1986). However, mobility of deer and elk is not restricted by fences, levels of forage use or specified dates (Lyon and Ward 1982). Migration probably occurs in conjunction with developing phenological stages of plant growth (Nelson and Leege 1982, Adams 1982). Putman (1986) speculated early grazing by deer and elk could stimulate increased production on numerous grass species. In contrast, livestock are usually confined by fences for a specific time period or until a desired level of forage is removed. Management with respect to timing and intensity of grazing by livestock could have significant negative influences on plant health, nutritional quality, and the quantity and quality of forage which could be grazed later by either livestock or big game (Lyon and Ward 1982).

The mobility, feeding habits, and densities of deer and elk adversely influence the practicality of large scale improvements in forage quality and quantity by conditioning the grassland forage resource through controlled grazing to increase nutritional quality. On the other hand, confining livestock within particular areas for a specified time period to achieve a specific level of removal of plant material through grazing could result in improvement in forage quality and availability for the sustenance of livestock and migrating deer and elk (Anderson and Scherzinger 1975, Willms et al. 1979).

PROBLEM STATEMENT

Deer, elk, and cattle all graze on publicly owned lands in the Blue Mountains. Both interspecific and intraspecific competition for forage can occur (Klemmedson 1967, Constan 1972). However, temporal, spatial distribution and the intensity of grazing can be partially controlled, particularly in the case of livestock, to minimize these conflicts. In recognition of these facts and in keeping with the Multiple Use-Sustained Yield Act of 1960 (MUSY), (Thomas 1987), public land managers must periodically evaluate management criteria and demonstrate an effective means of achieving multiple-use objectives. Therefore, National Forests are to be managed for multiple use including production of timber, watershed, wildlife, livestock and recreation. If appropriate management that achieves multiple use and protects the land resource is achieved and sustained, then some balance must exist between plants and animals. This mandate implies allocation of resources among various multiple uses and user groups. As the wild land resource continues to decline and demands for resources increase, the intensity of this conflict will magnify (USDA Forest Service 1983).

The MUSY clearly indicates that some National Forests will be managed for production of forage for livestock and wild ungulates. However, the appropriate mix of domestic and wild ungulates has not been defined in law. Livestock numbers are strongly influenced by history and traditional levels of use. The regulation issued pursuant to the National Forest Management Act of 1976 (McCleary 1982) requires that "viable population" of all native wildlife species be maintained and well distributed within the planning area. How does the manager address this issue in new and innovative ways? The land manager, realistically, must either maintain or improve existing rangeland condition for the variety of uses, depending on current ecological status.

In conjunction with these mandates Forest Service land managers have some discretionary authority in determining priority of uses. For instance, one area may be delineated to be managed with emphasis for big game winter range and another for predominantly timber production (Thomas 1987). The scope and applicability of this research pertains to those areas identified as elk winter areas in the Blue Mountains. Quality forage for use by elk during the winter includes the variables of quantity, availability, palatability and nutritional content. Since managers need appropriate information for formulating management plans, my primary objective was to determine how bluebunch wheatgrass can be manipulated to improve the quality of forage for elk on winter ranges in the Blue Mountains.

Optimal forage conditions have a different connotation to different resource managers and at different scales. Often forage quantity or biomass is one attribute of optimum forage condition for elk. Thomas et al. (1979) suggested that forage areas for elk should constitute 60 percent of the summer-range landscape with emphasis on patterns that placed such areas within 100 meters of forest cover. In their discussion, however, quantity and quality of forage in these areas was not referenced. They also suggested that in areas where competition for forage exists between big game and livestock, a full consideration for forage allocation to deer and elk should be evaluated by the resource manager.

The quantity and availability of forage influences the criteria used in evaluating the quality of forage. Crude protein, dry matter digestibility (DMD) and digestible energy (DE) are quantifiable measures of quality, especially if ungulates are to meet basic metabolic rates (Hobbs et al. 1981, Nelson and Leege 1982). Forage quantity could be in excess of such needs but if DMD is low (<50 percent) the animals may have difficulty meeting daily energy requirements (4-6000 Kcal/d) (Nelson and Leege 1982, Hobbs et al. 1981, Ammann 1973).

Numerous investigators (Wallace et al. 1966, Duvall 1970, Hanson and Smith 1970, Skovlin et al. 1983, Bayoumi and Smith 1976, Hobbs and Spowart 1984) have indicated that forage quality can be improved by fertilization, seeding, prescribed burning, chemical curing of forage, and tree and shrub control. Most of these conclusions have been documented with research data. On the other hand, manipulation of forage by livestock to improve forage quality for big game populations is limited (Urness 1990, Kie and Loft 1990, Severson 1990, Anderson and Scherzinger 1975, Pitt 1986, Allayne-Chan 1986). However, as pointed out by Lyon and Ward (1982), elk prefer areas where light grazing has occurred. Therefore, grazing of grasses on rangelands by cattle and elk could have desirable effects. Leckenby et al. (1982) suggested that livestock grazing may provide good deer forage by maximizing availability of new growth.

Anderson and Scherzinger (1975) hypothesized that winter range forage for elk was improved with grazing or "conditioning" by cattle during late spring and early summer. They further hypothesized that if bunchgrasses were grazed by cattle during late spring to early summer, growth by grazed bunchgrasses would surpass that of ungrazed vegetation in both production and nutritive values by early fall before elk arrived on those winter ranges. They also indicated grazing during the boot-to-seed stage could be detrimental to plant health. These suggestions and conclusions were derived from their personal observations and those of colleagues. This hypothesis is important for two reasons. First, evidence suggests that forage on winter ranges rarely meets maintenance requirements for deer and elk (Baker and Hobbs 1982, Hobbs et al. 1981, Scotter 1980). Second, many Blue Mountain winter ranges, such as the Bridge Creek Elk Management Area, managed by the Oregon Department of Fish and Wildlife, are managed on this hypothesis to provide optimum big game use and quality forage for elk. Thousands of elk on numerous winter ranges are managed on this hypothesis. Where grazing programs are implemented based on this hypothesis the elk have responded positively.

In contrast to Anderson and Scherzinger's (1975) hypothesis, Skovlin et al. (1968) indicated as livestock use increased on summer ranges in the Blue Mountains deer and elk use decreased. Furthermore, deer and elk utilized ungrazed areas more than grazed areas. Skovlin et al. (1983) also indicated, through a study of pellet group distributions, that elk use declined 28 percent in one of three years on their study area in the Blue Mountains during the winter following spring (mid-April to early June) grazing by cattle. They concluded spring grazing by cattle neither improved forage condition nor winter use by elk.

Svejcar and Vavra (1985), working in the Blue Mountains, presented data on bluebunch wheatgrass showing crude protein decreasing from 18.3 percent in April to 11.5 percent in May and a low of 6.0 percent in July. The *in vitro* dry matter digestibility (IVDMD) on this same study dropped from a high of 68.6 percent in April to 67.7 in May and a low of 46.5 percent in July. Skovlin (1967), also working in the Blue Mountains of Oregon, reported crude protein declining from a high of 8.8 percent in July down to a low of 3.5 percent in October. There were some yearly differences in both studies, but the trends from both data sets were parallel. Therefore, quality of bluebunch wheatgrass, as measured in crude protein and IVDMD starts declining shortly after current year's growth is initiated. Once the plant has matured, the nutrient content is thought to be fixed or slightly decreasing, due to leaching, through the fall and winter months (Salisbury and Ross 1985). However, this phenomenon has not been documented.

I think the quality of fall, winter, and spring range forages should be classified by three categories: (1) the mature current year's growth from ungrazed plants, which has the nutritive content essentially fixed by water-shortage stress and temperature; (2) growth of plants grazed in late spring that continue growing (depending on soil moisture) after grazing and have their nutrient content fixed again by water-shortage stress and temperature; and (3) fall growth which is leaf tissue that begins growing in late summer or early fall depending on available moisture. The nutrient content of late-spring growth and mature vegetation throughout the spring-summer months has been evaluated by numerous researchers (Skovlin 1967, Svejcar and Vavra 1985, McReynolds 1977, Schommer 1978, McArthur 1977). However, nutrient content of growth from neither late spring-/early summer-grazed plants nor fall growth through the fall and winter months has been so documented.

OBJECTIVES

The objective of this research was to examine the Anderson and Scherzinger (1975) hypothesis that late spring/early summer grazing of bluebunch wheatgrass would prevent translocation of nutrients back to the root system, thus locking nutrients in the plant's herbaceous tissue, which would provide high quality forage for wintering deer and elk. In conjunction with this objective, I wanted to evaluate the different phenological growth forms of bluebunch wheatgrass to establish which growth stage would provide the highest quality forage for wintering deer and elk.

To address these objectives the following hypotheses were tested and evaluated:

1. Determine the nutrient content and digestibility of the following plant appendages: (1) first leaf, (in order from bottom, oldest leaf, up), (2) second leaf, (3) third leaf (newest leaf), (4) inflorescence, and (5) culm, all after plant maturity (mid- to late September).

   H_o: No difference exists between these plant parts in their nutrient content or digestibility after plant maturation.

2. Determine the nutrient content and digestibility of fall-growth plant material from all treatments in October, November, December, January, February and March.

A. H_o: No difference exists in nutrient content or digestibility by month of plant growth occurring between October and March.

B. H_o: No difference exists in nutrient content or digestibility by month of growth between treatments.

3. Determine if a difference occurs in nutrient content and digestibility between summer-cured plant parts from objective 1 and growth of plant material by months between October and April. This will determine if alternate freezing and thawing affect nutrient content.

H_o: No difference in nutrient content and digestibility exists between the plant parts described in objective 1 and the fall growth in October, November, December, and April.

4. Determine the nutrient content and digestibility of spring/summer growth from plants clipped to 2.5cm and 7.6cm stubble height spring treatments.

H_o: No difference exists between treatments in nutrient content or digestibility of spring/summer plant growth.

5. Determine the nutrient content and digestibility for plant growth after plant maturity (mid- to late September) from plants not clipped.

A. H_o: No difference exists in nutrient content or digestibility between unclipped cured vegetation and growth from plants clipped to 2.5cm or 7.6cm stubble height in the spring.

B. H_o: No difference exists between the unclipped summer-cured vegetation and fall-growth plant material exposed to alternate freezing and thawing from October through March.

6. Determine the nutrient content and digestibility of summer-cured vegetation not clipped after snow melt (mid-March) the following spring.

H_o: No difference exists in nutrient content or digestibility of summer-cured vegetation between October and March.

7. Determine the nutrient content and digestibility of the fall-growth vegetative material from within the snow shelters, which had been exposed to freezing and thawing, and fall growth which had been under snow cover through the winter months and collected in March.

H_o: No difference exists in nutrient content or digestibility between fall-growth plant material that has been exposed to freezing and thawing and fall-growth plant material which has been covered with snow.

8. Determine the available spring/summer forage production from the different clipping treatments at plant maturity.

H_o: No difference exists in production between the different spring-clipping treatments.

9. Determine digestible energy (DE) Mcal/kg DM of plant material from all treatments where dry matter digestibility has been analyzed.

The formula for determining this is:

DE (Mcal)/Kg DM = .051(percent DMD)-.7054 (Schommer 1978).

10. Determine fall-growth production of biomass in Kg/Hectare from the clipped and not-clipped vegetation treatments.

LITERATURE REVIEW

Rocky Mountain Elk Distribution and Energy Requirements

The Rocky Mountain elk subspecies represented approximately 75 percent of the estimated 500,000 elk occurring in North America in 1976 (Bryant and Maser 1982). They are distributed throughout the Rocky Mountains and Intermountain mountain ranges of the western United States and southern Canada (Bryant and Maser 1982). The majority of these lands are in public ownership and are managed by Federal agencies including the USDA Forest Service, and the USDI National Park Service and Bureau of Land Management. Although the states retain ownership of the animals and are responsible for their management, their habitats are primarily managed by the Federal land management agencies. It has been estimated that 93 percent of all elk existing in the continental United States are either year-round or part-time residents on National Forests (Thomas and Sirmon, 1985).

Because of land base changing due to the encroachment of civilization upon their traditional ranges (Potter 1982), the task of optimizing habitat to meet basic dietary requirements for deer and elk becomes very complex. Thomas et al. (1979) inferred optimum summer-range habitat for elk would be an area divided into 60 percent foraging areas and 40 percent hiding and thermal cover. The difference between hiding and thermal cover was described by Black et al. (1976). On elk winter ranges, Leckenby (1984), indicated their home range size was independent of cover (hiding cover assumed) or thermal cover ratios; however, the cover-forage ratio on his winter range study sites approximated the optimum summer-range cover-forage ratio. In contrast, Peek et al. (1982) hypothesized elk only need cover during extreme weather conditions involving high winds. They also stated elk primarily select preferred habitats composed of succulent vegetation and absent of human disturbance. Furthermore, the animals may prefer vegetation types with cover but it is not required and thermal cover is insignificant in thermo-regulation benefits to elk (Peek et al. 1982).

The preference versus requirement or advantage controversy continues today. Elk certainly occur where marginal or no available thermal cover, especially vegetative crown closure as defined by Thomas et al. (1979b), exists, such as Jackson Hole, Wyoming (Martinka 1969), Wind Cave National Park, South Dakota (Varland et al. 1978), portions of southern Idaho (Will 1979 and Yeo 1981), and in the sagebrush-grasslands of southern Washington (Richard et al. 1977). Historical records also indicate numerous populations occurred on the Great Plains where thermal cover was limited (Burpee 1907, Koch 1941 and Murie 1951). However, Thomas et al. (1988) contended that it is pointless to argue the issue, where cover is available they use it. Leckenby (1984) and Parker and Robbins (1984) suggest there is a thermo-regulation advantage of cover to elk. Skovlin (1981) concluded a multitude of interwoven factors dictate what habitats are selected and to identify a specific factor or set of factors becomes a formidable task.

When most authors reference the importance of cover they usually neglect to examine the nutritional requirements of elk or nutritional quality of their preferred forage species. Cover certainly could be an important environmental attribute, but if the nutritional quality of dietary intake is sufficient to meet energy requirements, regardless of climatic condition, then cover may be insignificant as a thermo-regulatory entity. Animals may also abandon cover to utilize higher quality foraging areas.

The standard metabolic rate for elk has not been determined. Therefore, the existing information on daily energy requirements has been extrapolated from data on deer or livestock, primarily cattle (Nelson and Leege 1982). A formula developed by Kleiber (1961) which correlates heat production to body weight is an accepted method for deriving interspecific average standard metabolic rates. Thus, 70 kilocalories per kilogram of body weight$^{.75}$ per day (70 Kcal/BW$^{.75}$/day) will be the base for subsequent calculations.

Nelson and Leege (1982) expanded the information on elk activity patterns from Craighead et al. (1973) and applied the energy expenditure rates that Moen (1973) had developed from livestock to predict energy expenditure rates for foraging, bedding, traveling (at 2.4 kilometers/hour), standing and ruminating for the 4 equinox seasons. With this information a cow elk weighing 236 kilograms (520 pounds) would need an estimated 6,035 kilocalories of energy per day to meet her average activity and maintenance requirements during the winter. Although gestation increases the daily energy requirements it is thought to be only significant during the last trimester of pregnancy (Nelson and Leege 1982) and, therefore, has not been added to this estimate.

Weight loss of livestock from western rangelands, starting in late August and occurring through mid-September, has been reported for Blue Mountain ranges (Holechek et al. 1981, Skovlin 1967). I hypothesize that the dietary crude protein concentrations in native grass forages during late summer and fall are below the protein requirements necessary to support domestic livestock maintenance requirements. These same basic metabolic functions may or may not be occurring within deer and elk populations in the Blue Mountains because of their reduced body size, level of production, and ability to select for premium plant appendages. Vavra et al. (1989) and Bell (1971) have reported that when the quantity of forage becomes limited the select feeders or smaller herbivores fare better than when quality becomes limited and roughage feeders or larger herbivores are favored. Data on weights or body conditions of wild ruminants during this time period are lacking in the literature.

Free-ranging deer and elk spend 40-60 percent of each day foraging for and consuming food (Wickstrom et al. 1984). The energetic cost associated with this activity represents an important component of the animal's daily energy budget (Wickstrom et al. 1984). On spring/summer ranges when availability of quantity and quality forage usually is not limiting, energetic costs would be minimized (Wickstrom et al. 1984). However, when quality and quantity decline during late summer and early fall, the energy cost for maintenance and production of resources increases (Nelson and Leege 1982). During the winter months when both quality and quantity of forage could be severely reduced, maximum energetic costs for maintenance would be required (Wickstrom et al. 1984).

The phenological stage of plant growth and availability to grazing animals are directly related to forage intake rates. Intake rates for elk are greater on grass growth, which has a higher dry matter digestibility value than mature forage, than the rate of intake on mature forage (Hobbs and Swift 1988). Forage abundance and phenological development can affect both net-energy-symmetry management practices which manipulate forage on winter ranges and foraging efficiencies when energy balances are critical (Wickstrom et al. 1984). Thus, I hypothesize that whatever can be accomplished to improve forage quality and availability for deer and elk on their winter ranges should improve opportunities for winter survival by reducing energetic cost for foraging.

Bluebunch Wheatgrass

Bluebunch wheatgrass on western rangelands is an indicator of range health, productivity and potential ungulate production (Quinton et al. 1982). Through misunderstandings about the physiological needs and functions of bluebunch wheatgrass the plant has been exploited through over grazing by livestock from much of its original distribution on rangelands throughout western North America (Hanson and Stoddart 1940, Miller et al. 1986). With this over exploitation came diversity and structural changes within the plant communities that have decreased the potential productivity of palatable herbage for both domestic and wild ungulates (Miller et al. 1986). Explanations for the disappearance of bluebunch wheatgrass have been offered by Daubenmire (1970) and Mack and

Thompson (1982) who indicated bluebunch wheatgrass did not evolve with heavy grazing and therefore its tolerance to grazing is limited. In addition, poor management by early livestock operators more interested in short-term economic returns than resource protection have contributed to its decline. However, with prudent grazing, Sneva et al. (1984) found frequencies of bluebunch wheatgrass similar between a 50-year exclosure and adjacent area which had been grazed by cattle for more than 50 years.

Bluebunch wheatgrass occurs on many different soil types ranging from well-drained loamy soils to shallow calcareous hardpans (Heady 1950). Drought conditions occur frequently throughout its range (Miller et al. 1986). The northern limit of bluebunch wheatgrass is Alaska, easterly it ranges to western South Dakota, southerly to New Mexico and California, and throughout the Great Basin region (Hitchcock and Cronquest 1973). It is found most frequently in the 20.3-43.2 cm precipitation zone, but also occurs within the 102 cm precipitation zone (Pitt 1986) and ranges in elevation from 152.3-2743.2 meters (Winward 1980). Spring growth is initiated when soil temperatures approach 5-6° C. at 10 cm depth and accelerated growth occurs around 20-25° C. providing soil moisture remains favorable (De Puit and Caldwell 1975).

On the lower, more arid precipitation zones it is co-dominate with several *Artemisia* subspecies. *Artemisia tridentata* ssp. *wyomingensis*/*Agropyron spicatum* is the most common and probably largest habitat type which bluebunch wheatgrass occupies (Miller et al. 1986). On more mesic sites bluebunch wheatgrass is found in plant associations with Idaho fescue (*Festuca idahoensis*) and

Sandberg bluegrass (Poa secunda) (Miller et al. 1986). In the Blue Mountains of Oregon, bluebunch wheatgrass and Idaho fescue usually are found together on deeper soils and adjacent to coniferous forests (Hall 1973). The bluebunch wheatgrass and Sandberg bluegrass communities are found on shallow soils and are usually the main components of most grassland communities (Hall 1973).

Nutritional Value

Bluebunch wheatgrass has been, and, where it still occurs, is an important component in diets of domestic and wild ruminants. It is extremely productive, very palatable, and the most widely distributed grass in Western North America (Anderson 1991). Primarily because it grows across a very broad elevational gradient, with proper management grazing animals can utilize it by following the phenological development from lower to higher elevations with minimal impacts on plant health and plant community structure.

The nutrient content of bluebunch wheatgrass is highest during the early phenological stages, but, once moisture and temperature stress is initiated, the quality declines quite rapidly (Cook et al. 1956). In the Blue Mountains, Svejcar and Vavra (1985) found crude protein and dry matter digestibility high in April but significantly lower in both values by July. In Central Washington, McReynolds (1977) found crude protein in bluebunch wheatgrass was 21.7 percent in April, 14.2 percent in June, and 3.1 percent in October. Cook et al. (1956) in Utah detected a decrease in digestible crude protein from 9.9 percent on June 1 to 5.2 percent on June 23. Westenskow

(1991), working in the Blue Mountains, found IVDMD ranging from 82 percent in April to a low of 32 percent in October. Once the plants have reached maturation and cured the nutrient content has declined (Skovlin 1967). Although the quality becomes less than desirable most classes of livestock will graze the plants (Skovlin 1967). An exception to this occurs when late summer and early fall precipitation promotes fall growth. This "green-up" can provide valuable fall and winter grazing for both livestock and wildlife (Miller et al. 1986).

Regardless of seasonal flucuation of forage quality, bluebunch wheatgrass remains an important forage species in diets of wild ruminants. Skovlin and Vavra (1979), working on 5 known elk and deer winter ranges scattered through the Blue Mountains of Oregon and Washington, found bluebunch wheatgrass in elk diets from all study areas. A thorough review on the importance of winter food habits of elk was conducted by Kufeld (1973), who reported where bluebunch wheatgrass occurred it was eaten by elk. McReynolds (1977) and McArthur (1977) both found bluebunch wheatgrass in Central Washington the primary food source for elk during the winter period.

Grazing Tolerances

Early, heavy grazing of bluebunch wheatgrass has been considered detrimental to plant health because of its upright stature, slender shoots, early elevation of apical meristems, inability to produce axillary buds, and high ratio of vegetative to reproductive shoots (Branson 1956, Harris 1967, Evans and Tisdale 1972, Miller et al. 1986). Bluebunch wheatgrass appears to be most sensitive to defoliation when root reserves are minimal (McIlvanie 1942). Other researchers (Daubenmire 1940, Stoddart 1946, Blaisdell and Pechanec 1949, Trlica and Cook 1971) found bluebunch wheatgrass sensitive to mortality and production when clipping just before and during the boot state. This probably coincides closely with minimum root reserves.

McLean and Wikeem (1985) observed 58 percent mortality in plants clipped each week to a 10 cm stubble height throughout the growing season. Pitt (1986) reported an 89 percent reduction in flowering stems when plants were clipped to 15.24 cm stubble height during the boot stage.

In an attempt to assure the continued existence of original bluebunch wheatgrass communities, Stoddart (1946) demonstrated what he considered the proper level and timing of livestock grazing to minimize plant mortality. He reported that plants could tolerate weekly clipping to a 2.5 cm stubble height from mid-April through the first week in May with <u>no</u> mortality. Clipping to a 2.5 cm stubble height from the first week in May through June, however, produced heavy mortality. With this criteria established, note that Blaisdell (1958) disregarded timing of use and suggested that the opening of cattle grazing season on the Snake River plains in Idaho should occur when bluebunch wheatgrass obtained 6.4 cm of growth.

Most observations or data presented in the literature were derived from grazing or clipping studies conducted in late spring and early summer. The later the grazing or clipping, the less likely it was that herbage production was affected and plant mortality suffered. Timing of defoliation can influence the plant's ability to produce growth, primarily because of higher temperatures and limited moisture (Stoddart 1946, Wilson et al. 1966). This could be due to photosynthetic rates which have been increasing per surface unit of leaves but decreasing overall photosynthesis on a plant-by-plant basis (Caldwell et al. 1983, Nowak and Caldwell 1984). However, this reduced photosynthesis and delayed older leaf maturation approximately two weeks (Caldwell et al. 1983).

Depending on the amount of late summer or early fall precipitation (2.5-7.5 cm) bluebunch wheatgrass has the potential to begin fall growth. The impacts of fall grazing of fall growth on plant survival or carbohydrate reserves have not been reported for bluebunch wheatgrass. When precipitation accumulates to initiate fall growth then that growth will continue, if soil temperatures remain above approximately 5° C (Anderson 1991), until about November. Tillers from fall growth will continue to grow the following spring and about 75 percent will survive the winter conditions with the oldest leaf senescing during the winter (Nowak and Caldwell 1984). West et al (1979) reported the life span on bluebunch wheatgrass was extended by fall grazing compared to ungrazed plants.

The hypothesis presented by Anderson and Scherzinger (1975) and discussed earlier led the Canadian government into some major grazing management systems to condition forage for big game animals without quantifing their hypothesis. The literature base for this theoretical concept and technique was evaluated by Allayne-Chan in

1986. In conjunction with her literature evaluation, Pitt (1986) reported results from research conducted on conditioning bluebunch wheatgrass in southwest British Columbia, Canada, to improve forage quality for elk based on the same hypothesis.

Allayne-Chan (1986) evaluated an extensive literature review of grazing or clipping affects on bluebunch wheatgrass and found data which supported and refuted the Anderson and Scherzinger (1975) hypothesis. Allayne-Chan (1986) observed that: (1) the nutrient content of conditioned plants was higher than unconditioned except for nonstructural carbohydrates; (2) nitrogen leaching is independent of concentrations of nitrogen in the foliage; and (3) depending on season and method of conditioning, the production of foliage results have ranged from positive to negative. She also pointed out there was circumstantial evidence of translocation of carbohydrates from foliage to underground reserves during the curing process. Furthermore, there was no published information pertaining to physiological processes which resume following summer dormancy.

Pitt (1986) concluded that there were significant improvements in forage quality of bluebunch wheatgrass following conditioning treatments. The results indicated lower (5.3 percent) acid detergent fiber (ADF) and higher (3-7.7 percent) crude protein, calcium (.18-44 percent) and phosphorous (.06-.18 percent) on conditioned plants versus plants not conditioned. The study treatments involved clipping plants at the following phenological stages: (1) boot; (2) emergence; (3) flowering; and (4) seed formation. The results indicated a progress of higher forage quality values the later the treatment, which indicate treatment for maximum forage quality of remaining plant-growth material should occur around the seed formation (1-5 percent greater crude protein than control) phenological period. However, the risks to plant health, reproduction, and survival are diminished when this occurs. And this is pointed out by the author, who listed mortality rates at 50 percent for defoliation at emergence, 60 percent at flowering, and 60 percent at seed formation.

In essence, Pitt's (1986) conclusions were that Anderson and Scherzinger's (1975) hypothesis on improvements of forage quality, as measured by crude protein, ADF, calcium and phosphorous, were valid. However, several environmental factors which could have significant impacts on these conclusions need further discussion. Pitt (1986) made no reference to the timing of precipitation especially in the mid- to late summer period. In addition, there was no mention of soil moisture conditions through the study period. The amount of precipitation referenced is 4-5 times what could be expected over most habitat types where bluebunch wheatgrass is commonly found. Temperature and length of growing season are additional factors which could influence bluebunch wheatgrass response to defoliation. The 210-day frost-free period is approximately twice as long as could be expected on most areas where bluebunch wheatgrass exists.

Westenskow (1991), observed bluebunch wheatgrass conditioned by clipping to a 7.6 stubble height just prior to the boot stage, and in November found no significant difference in percent calcium and phosphorus levels between spring-clipped plants and plants not clipped. This is a contrast to Pitt's (1986) results. The environmental factors may be the differences.

THE STUDY AREAS

Three separate study sites were located within Rocky Mountain elk winter ranges in the Blue Mountains of Oregon. The study areas were between 35 and 50 kilometers southwest of La Grande, Oregon (Figure 2). All three study sites were located on USDA Forest Service lands. The three study areas were referenced as Horse Pasture, Winter Ridge, and McCarty Springs. The Horse Pasture area was within the Starkey Experimental Forest and Range at an elevation of 1381 meters with an easterly aspect. The legal description is USGS Quad: Sullivan Gulch, Oregon, T. 4 S., R. 34 E., Sec. 14, center of the NW 1/4. Winter Ridge is on the Wallowa-Whitman National Forest with an elevation of 1366 meters and with a south, southwest aspect. The legal description is USGS Quad: Little Beaver Creek, Oregon, T. 4 S., R. 36 E., Sec. 19, NW 1/4 of the SW 1/4. McCarty Springs is also located on the Wallowa-Whitman National Forest at an elevation of 1274 meters and with a west aspect. The legal description is USGS Quad: Marley Creek, Oregon, T. 4 S., R. 35 E., Sec. 20, NW 1/4 of the SW 1/4.

Climate

The climate is continental with cold winters and warm summers. The average growing season is 120 days and occurs from mid-May to mid-September. However, frost can occur during any month. The mean temperature at Starkey for July and January are 18° C. and -4°C,

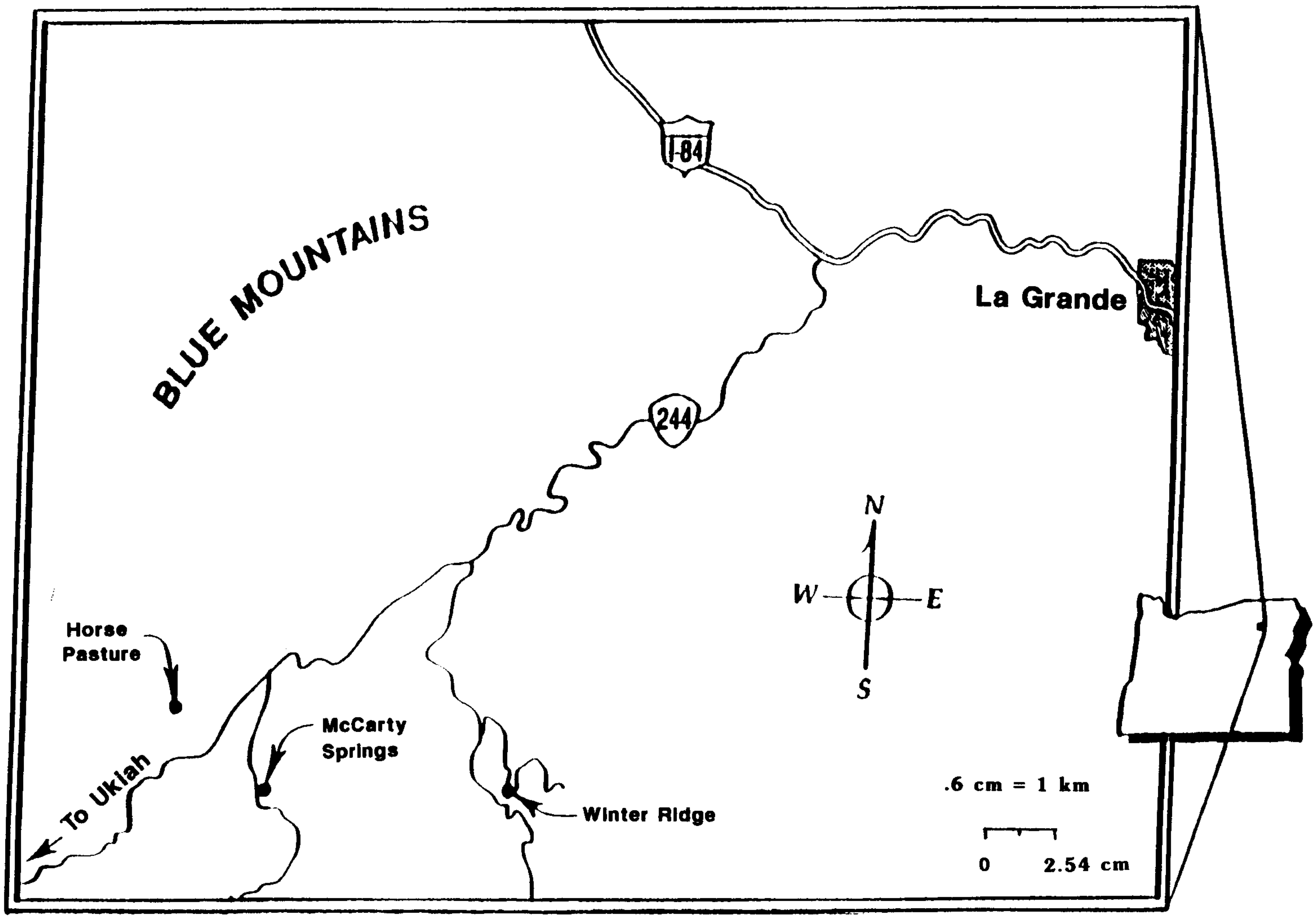

Figure 2. Location of Horse Pasture, McCarty Springs, and Winter Ridge Study Areas.

respectively (Strickler 1966). Monthly temperatures (^{o}C) data from adjacent weather station at Ukiah, Oregon are presented in Table 1. Site specific temperatures (^{o}C) for the Horse Pasture, Winter Ridge and McCarty Springs are presented in Tables 2, 3, and 4 respectively.

Annual precipitation at Starkey averages 53 cm. About 60 percent of this precipitation comes during the winter months in the form of snow. The remaining precipitation is deposited as rain throughout the year. However, accumulation of snow has been observed at 1219 M and above during every month except August within the last ten years. Summer and fall rains are extremely variable and unpredictable (Skovlin 1967). Precipitation (cm) data from Ukiah, Oregon and Starkey Experimental Forest from 1985 to December 1992 is presented in Table 5. Site specific precipitation (cm) for the Horse Pasture, Winter Ridge and McCarty Springs is presented in Table 6.

Vegetation and Soils

Plant community types on all three sites were classified as "Bunchgrass on shallow soil, gentle slopes, GB-49-11", (Hall 1973). The dominant species in this plant community type are Bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), Sandberg bluegrass (*Poa secunda*), and western yarrow (*Achillea millefolium*). The soils are stoney and shallow with a loam to silt-loam texture, with some bare ground and erosion pavement present.

Soils in the Horse Pasture study area were classified as Anatone series by Dyksterhuis and High (1985). The other two sites have been classified as Anatone-Bocker (Appendix 1). Anatone series characteristics indicate they were derived from basalt and formed from colluvium and residuum actions with some loess and volcanic ash present in the surface layer (Appendix 1). Vegetation production is limited by shallowness and droughtiness of the soil (Dyksterhuis and High 1985). Westenskow (1991) indicated that top soil concentrations of calcium and phosphorus were within reported averages at both McCarty Springs and Winter Ridge sites, however, phosphorus was below average in the subsurface horizons.

Table 1. Monthly Temperatures (^{o}C) for Ukiah, Oregon, with high, low and mean values for 1986-1988.

	Ukiah	1986			1987			1988		
Mon.	10-Yr Av	High	Low	Mean	High	Low	Mean	High	Low	Mean
Jan.	-4.1	13.3	-13.9	-1.3	11.7	-31.1	-6.6	8.3	-19.4	-3.9
Feb.	-0.1	21.1	-15.0	1.0	10.6	-20.6	-1.3	16.7	-17.2	0.9
Mar.	2.4	22.2	-7.8	5.9	17.8	-9.4	2.6	16.7	-8.9	1.4
Apr.	5.2	27.8	-9.4	5.0	30.6	-7.8	8.8	*	*	*
May	8.9	32.2	-6.7	9.5	32.2	-6.7	10.8	*	*	*
Jun.	12.9	33.9	-3.3	15.6	34.4	-2.8	14.3	*	*	*
Jul.	16.1	33.3	-1.7	14.1	36.7	0.0	16.1	37.8	4.4	19.3
Aug.	15.9	36.1	1.1	17.6	36.1	-1.7	14.7	37.8	1.7	17.3
Sep.	11.7	30.0	-5.0	9.3	36.1	-7.8	12.9	*	*	*
Oct.	6.9	26.1	-8.9	7.7	31.1	-11.7	7.5	29.4	-1.1	13.5
Nov.	1.3	15.6	-17.2	1.3	18.9	-12.2	2.1	13.3	-13.3	-0.6
Dec.	-1.9	7.2	-12.2	-2.9	13.9	-20.6	-2.3	7.2	-20.6	-4.8

* Missing Data

Table 2. Monthly Temperatures (^{o}C) for the Horse Pasture Study Area.

Mon.	1986 High	1986 Low	1986 Mean	1987 High	1987 Low	1987 Mean	1988 High	1988 Low	1988 Mean
Jan.				8.9	-17.8	-4.8	3.9	-21.1	-4.4
Feb.				12.2	-13.3	-1.1	11.1	-15.6	-1.6
Mar.				17.8	-10.0	1.3	15.6	-14.4	0.5
Apr.				29.4	-7.8	7.9			
May				28.9	-5.6	10.3			
Jun.				32.8	-2.2	14.7			
Jul.				35.6	.56	15.3			
Aug.				35.0	1.1	16.8			
Sep.				35.0	-3.3	15.1			
Oct.				30.6	-6.1	10.4			
Nov.				14.4	-12.2	0.7			
Dec.	5.0	-15.0	-5.1	11.7	-15.0	-2.7			

* Missing Data

Table 3. Monthly Temperatures (^{o}C) for the Winter Ridge Study Area.

Month	1987 High	1987 Low	1987 Mean	1988 High	1988 Low	1988 Mean
January	9.4	-25.6	-6.1	7.8	-22.2	-4.9
February	12.8	-18.3	16.5	15.6	-18.9	1.1
March	18.9	-11.1	2.5	17.8	-10.0	.94
April	*	*	*	25.6	-7.2	7.7
May	30.0	-5.6	11.2			
June	32.8	-1.7	13.8			
July	37.2	1.6	15.9			
August	36.7	2.2	17.9			
September	35.0	-2.2	16.6			
October	30.6	-4.4	11.8			
November	17.2	-11.1	1.6			
December	11.1	-16.7	-3.6			

* Missing Data

Table 4. Monthly Temperatures (^{o}C) for the McCarty Springs Study Area.

Month	1986 High	1986 Low	1986 Mean	1987 High	1987 Low	1987 Mean	1988 High	1988 Low	1988 Mean
Jan.				8.3	-17.7	-5.2	5.6	-22.2	-5.4
Feb.				8.3	-13.9	-1.4	15.7	-22.2	0.2
Mar.				19.4	-10.6	2.5	17.2	-11.1	1.6
Apr.				*	*	*			
May				27.8	-6.1	11.7			
Jun.				36.1	-2.2	15.4			
Jul.				37.8	1.7	16.6			
Aug.				37.2	0.6	17.4			
Sep.				36.7	-3.8	15.7			
Oct.				32.2	-5.0	11.8			
Nov.				17.2	-12.8	1.4			
Dec.	6.7	-12.2	-3.7	12.8	-17.8	-3.2			

* Missing Data

Table 5. Monthly Precipitation (cm) Data from Ukiah, Oregon and Starkey Experimental Forest with Monthly High and Low Values/Week.

Month	Ukiah 10-Yr Ave	Starkey 8-Yr Ave	1986 High	1986 Low	1987 High	1987 Low	1988 High	1988 Low
Jan.	4.17	5.27	5.92	5.64	6.07	5.92	7.54	5.46
Feb.	3.63	5.22	13.34	9.45	4.17	4.12	3.58	1.24
Mar.	3.68	5.92	4.69	3.05	*	4.47	8.66	3.05
Apr.	3.40	4.87	3.81	1.93	2.77	1.35	5.61	4.42
May	3.86	6.37	5.11	3.71	4.39	3.33	5.23	5.21
Jun.	2.77	4.47	2.34	0.71	3.10	2.26	4.55	3.76
Jul.	1.96	1.68	1.80	1.73	2.31	2.03	0.03	0.00
Aug.	2.90	2.32	0.51	0.00	1.14	0.28	1.04	0.81
Sep.	2.03	2.54	5.26	4.19	0.18	0.13	2.26	1.47
Oct.	3.38	2.69	2.26	2.16	0.13	0.10	0.53	0.25
Nov.	5.11	7.87	9.32	6.60	3.66	3.10	10.19	6.50
Dec.	5.41	4.13	1.39	1.12	4.90	4.70	6.20	3.84
Annual	42.30	53.35	55.75	40.29	32.82	31.79	55.42	36.01

* Missing Data

Table 6. Monthly Precipitation (cm) for 1986 and 1987 from June through December at the Different Study Areas.

	Horse Pasture		Winter Ridge		McCarty Springs	
	1986	1987	1986	1987	1986	1987
June	1.32	2.41	.61	2.95	1.84	2.59
July	2.26	1.14	1.03	1.30	.51	.79
August	.28	.08	.08	T	.17	T
September	3.62	.13[1/]	6.07	T	1.91	T
October	1.78	.13[1/]	ND	T	8.15	T
November	8.99	3.66[1/]	1.96	.99	2.16	.89
December	.97	4.90[1/]	.41	ND	.41	ND
Total	19.22	12.45	10.16	5.24	15.15	4.27

ND = No Data
T = Trace not measurable
1/ Data from Starkey Headquarters 1 Km from study site.

Grazing History

All three study areas occur within the same general vicinity and are referred to locally as the Starkey area. Livestock grazing first occurred in 1864 by 200 head of steers that were being driven to the Idaho mines (Skovlin 1991). Some grazing by cattle and horses may have occurred earlier than this by animals of pioneers traveling the Oregon Trail. The Cayuse Indians from the Umatilla River Area, which is approximately 80 km northwest of Starkey, first acquired horses between 1710-1720. They probably used the area extensively for collecting roots, herbs, hunting and fishing. Therefore, the first livestock use by horses in the Starkey area probably occurred during this time period (Skovlin 1991).

From the 1860's until 1905 when the Forest Reserves were established, the areas received extensive grazing by cattle that were driven through the area to a rail head in Cheyenne, Wyoming.

Cattle, sheep, and horses owned by homesteaders grazed the area year-long during this same time period (Skovlin 1991). Although the stocking rates were quite liberal during the National Forest establishment phase (early 1900's), some grazing control was implemented and the season of use was basically cut in half by 1910 (Skovlin 1991). It was about 1940 before the stocking rates and season of use were brought into an equilibrium with the vegetation base for the area.

The Horse Pasture plot is located on the Starkey Experimental Forest and Range, which is also the Starkey Cattle and Horse Allotment that was established in 1907. The stocking rate in 1907 was .81 hectares per Animal Unit Month (AUM) and the season of use was from mid-April to November 1 (Skovlin 1991). Once the Experimental Forest was established in 1940, the stocking rate was decreased to 3.04 hectares/AUM and the season of use was reduced to 120 days. Shortly after establishment of the Experimental Forest and Range, the area was divided into two pastures and a deferred-rotation grazing system installed.

Although numerous grazing systems have been implemented or evaluated with research projects, the area has had at least a deferred-grazing system in place since it was established. Since the Horse Pasture was fenced in 1975 to create a pasture for Forest Service horses, it was never used for that purpose. As a result, the only grazing within the pasture since 1975 has been by deer and elk. The plant community on this site is in fair condition with the majority of bluebunch wheatgrass plants small bunches ranging in diameter from 2.5-7.6 cm indicating recent establishment.

The Winter Ridge area also has a similar grazing history to that of the Horse Pasture. From 1943 to 1961 the area was in a sheep allotment. The permittee converted the allotment to a cattle use allotment in 1963. From 1943 to 1962, the permit was for 1,000 head of sheep, which equates to 3.24 hectares/AUM. Season of use from 1943 to 1957 was June 1 through October 31. Starting in 1958, the season of use was reduced 2 weeks and started in the middle of June. In 1962, the permit was converted to 200 head of cattle and the season of use remained from mid-June to October 31 in a deferred-rotation grazing system. The plant community on this site is classified as fair condition, and the bluebunch wheatgrass plants are in a seedling form. The study plots were fenced to prevent livestock grazing in the summer of 1986.

The grazing history of the McCarty Springs area is similar to that of the Horse Pasture and Winter Ridge areas. In 1949, the area was converted from a cattle allotment to a sheep allotment. The Forest Service permit issued in 1946 was for 1,000 head of sheep which equates to 3.24 hectares/AUM. Season of use from 1946 to 1967 was 2.5 months starting on July 1 and ending in mid-September in a season-long grazing system. In 1967, the permit was modified to extend the use to 3 months, mid-June to mid-September, with the same number of animals. The plant community on this site is classified as being in good condition and the bluebunch wheatgrass plants are large (10-18 cm in diameter), with the plant centers dying out which indicates mature plants. The study plots were fenced in 1986 to protect them from livestock grazing.

In conjunction with elk use the areas are also year-round habitats for mule deer. The severity of winter dictates the amount of time either species use the areas during the winter. With the exception of deep snow conditions, deer and elk will occupy the area from late November through March. When the deep snow conditions do occur, they will migrate to lower elevations.

Population densities of deer and elk within the general area have often been questioned and debated. The Lewis and Clark Expedition in 1805 traveled just north of the study area and found big game animals along their route in late September scarce (Bakeless 1964). Bonneville in 1834 remarked about a great number of elk being driven out of the mountains by snow into valley bottoms just east of LaGrande, Oregon (Evans 1990). Fremont, traveling through the area in 1842 on a trip from Boise, Idaho, to Walla Walla, Washington, contacted a Cayuse Indian hunting party in late September and only a few miles east of Starkey; the only animals they had harvested were hares (these were probably either whitetailed or blacktailed jack rabbits, *Lepus townsendii*, *Lepus californicus*). In his diary he referenced taking on provisions, including meat, before starting the journey (Fremont 1845). The Fremont Expedition continued traveling through the area just south and west of the study area and also referenced the scarcity of big game animals within the area (Fremont 1845). However, by the time Fremont traveled through the area numerous immigrants traveling the Oregon Trail had moved through and could have impacted big game densities.

Regardless of what the historical elk populations were before 1900, by the early 1900's their population densities were very low. Starting in 1905, legal elk hunting in Oregon was terminated and was not permitted for the next 28 years (Bryant and Maser 1982). In 1921, the USDA Forest Service estimated the elk population just south of the Starkey in the North Fork, John Day River headwaters (approximately 12-16,000 hectares) wintering area at 360 animals. By 1931, their elk population estimates were 3,200 animals, and, by 1938, the population was estimated at 10,000 animals. This represents a 2,160 percent increase in only 17 years (Cliff 1939). The winter range and much of the summer range was severely over grazed by deer and elk and the population started expanding into the adjacent areas (Cliff 1939). This population of elk was probably the origin for most of the elk throughout the study area and southern part of the Blue Mountains.

Aerial surveys by Oregon Department of Fish and Wildlife have indicated the wintering populations of elk on Winter Ridge and McCarty Springs areas are increasing. Their three-year averages for 1969 to 1971 were 179 elk on Winter Ridge (approximately 4,500 hectares) and 107 elk on McCarty Springs area (approximately 3,500 hectares). Their three-year averages on the same areas for 1988 to 1990 were 333 elk and 276 elk, respectively (Westenskow 1991).

METHODS

Vegetation Sampling

Plot Establishment

The criteria used in selecting the study areas were: (1) location on a known elk winter range; (2) an *Agropyron spicatum* plant community type; (3) the sufficient density of plants adequate to allow extensive sampling; (4) enough difference in elevation to produce differing plant phenological development; (5) enough slope and aspect differences to evaluate differences in values attributable to exposure; (6) the availability of detailed grazing history; and (7) Federal ownership to allow access. Study areas meeting all criteria were selected and fenced to exclude livestock. Each exclosure was approximately one hectare in size. In conjunction with the exclosures on the Horse Pasture and McCarty Springs areas, snow shelters were constructed to allow for winter sampling of snow-free vegetation. There was no snow shelter on the Winter Ridge study site. Both the exclosures and snow shelters were divided into eight equal plots (Figures 3, 4, 5, 6 and 7). Each plot was then further divided into three subplots so that the four vegetation treatments could be randomly assigned one of four treatments in two of the three subplots. This produced a randomized design.

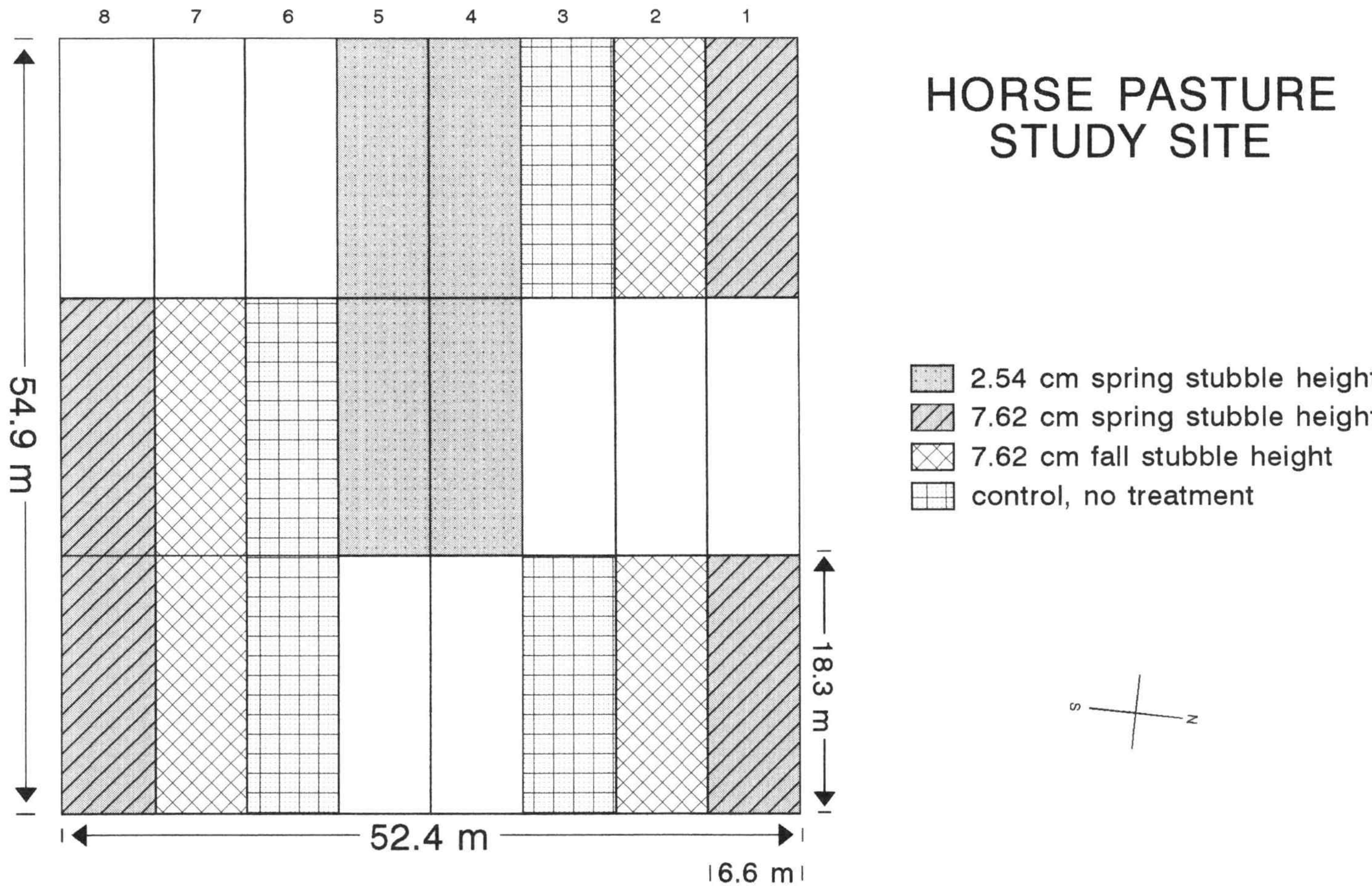

Figure 3. The Horse Pasture Study Area.

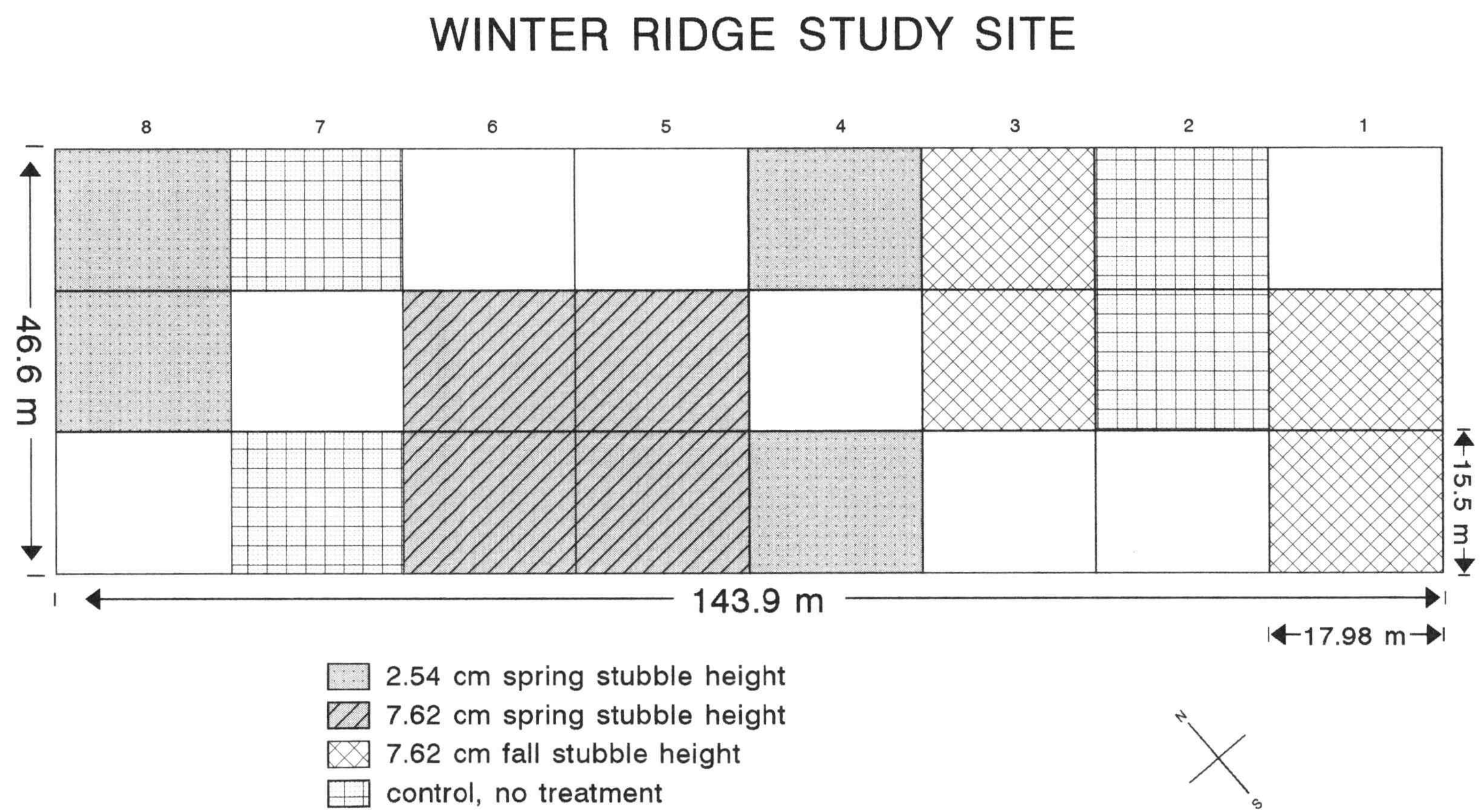

Figure 4. The Winter Ridge Study Area.

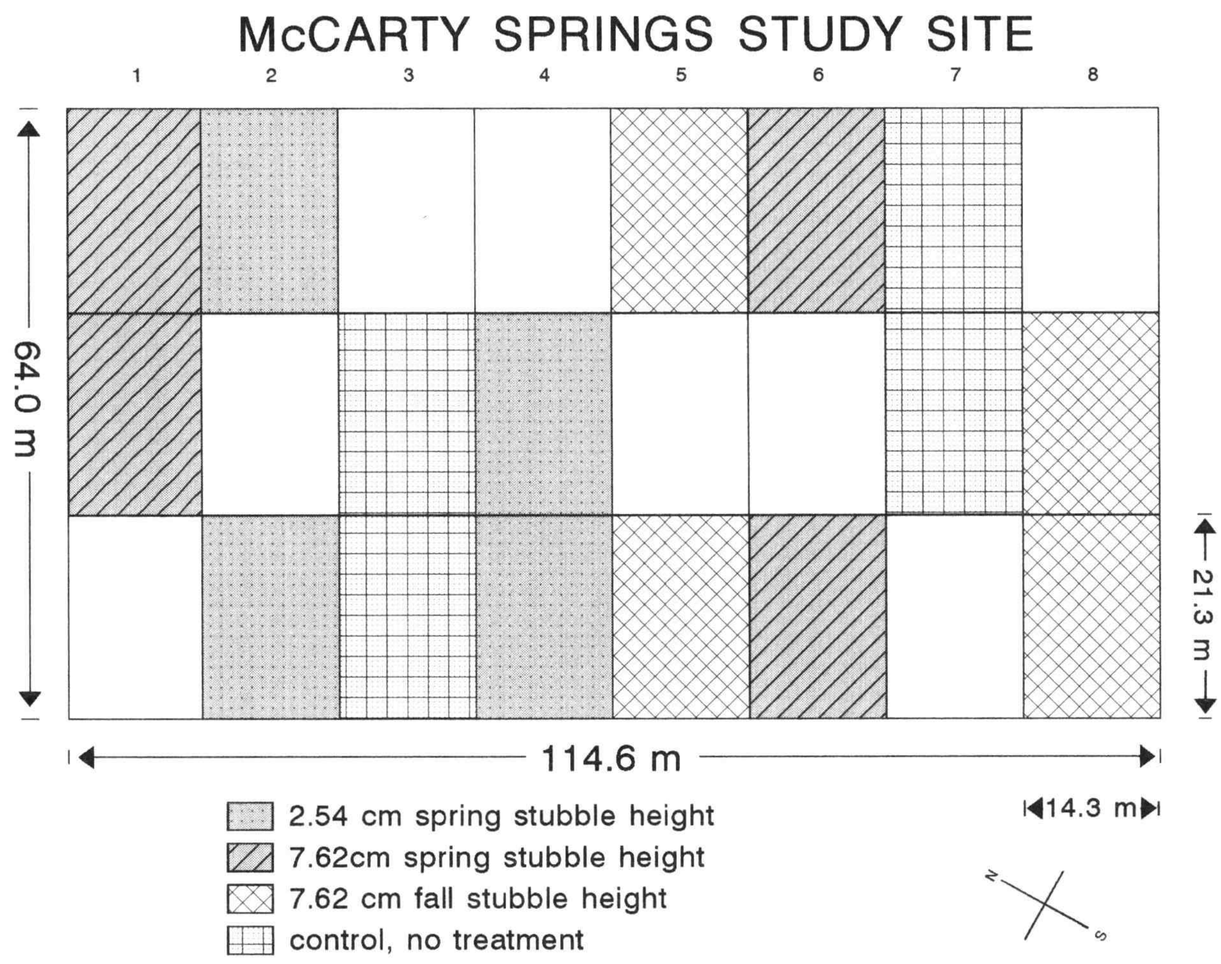

Figure 5. The McCarty Springs Study Area.

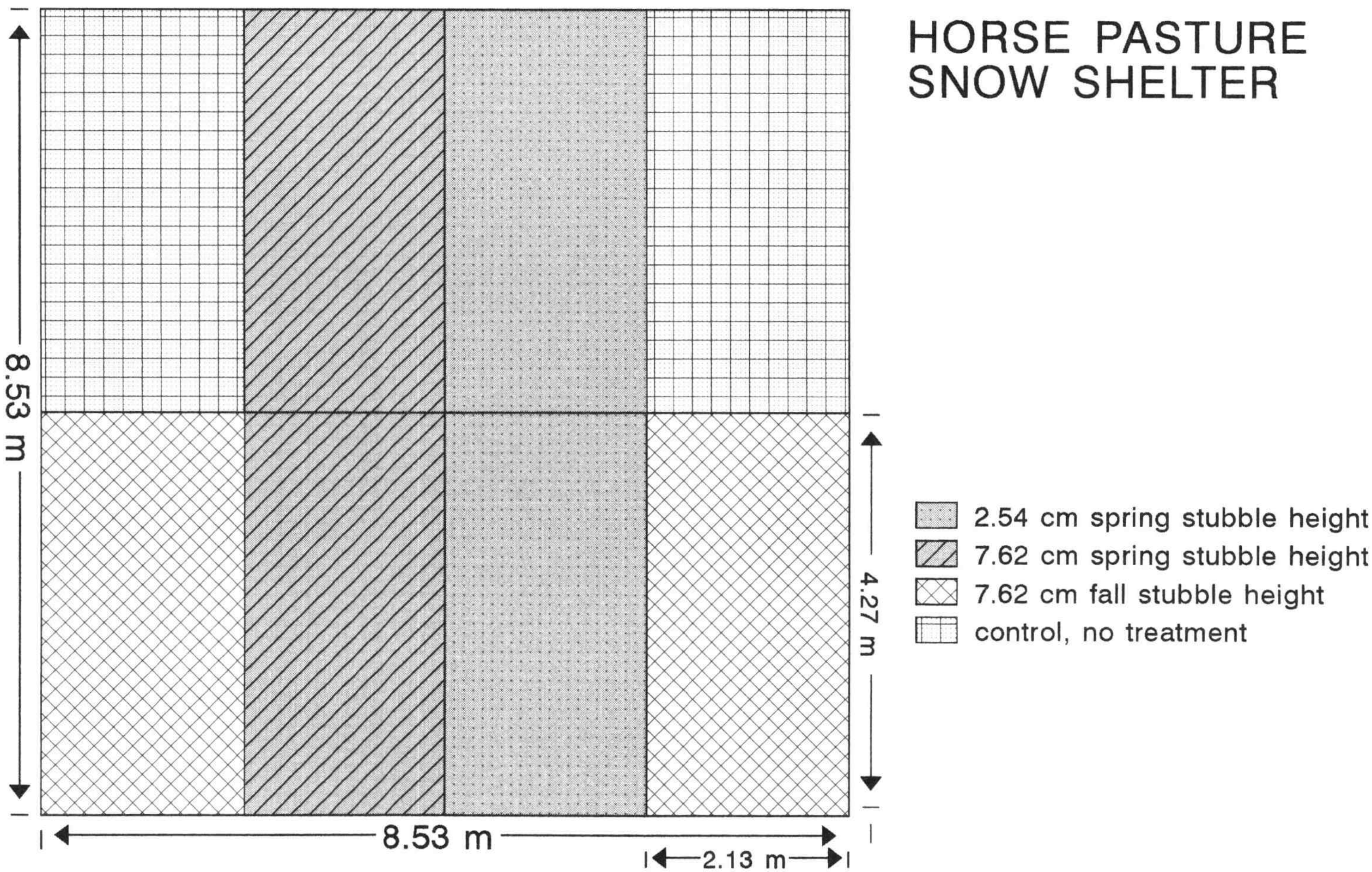

Figure 6. The Horse Pasture Snow Shelter Study Plots.

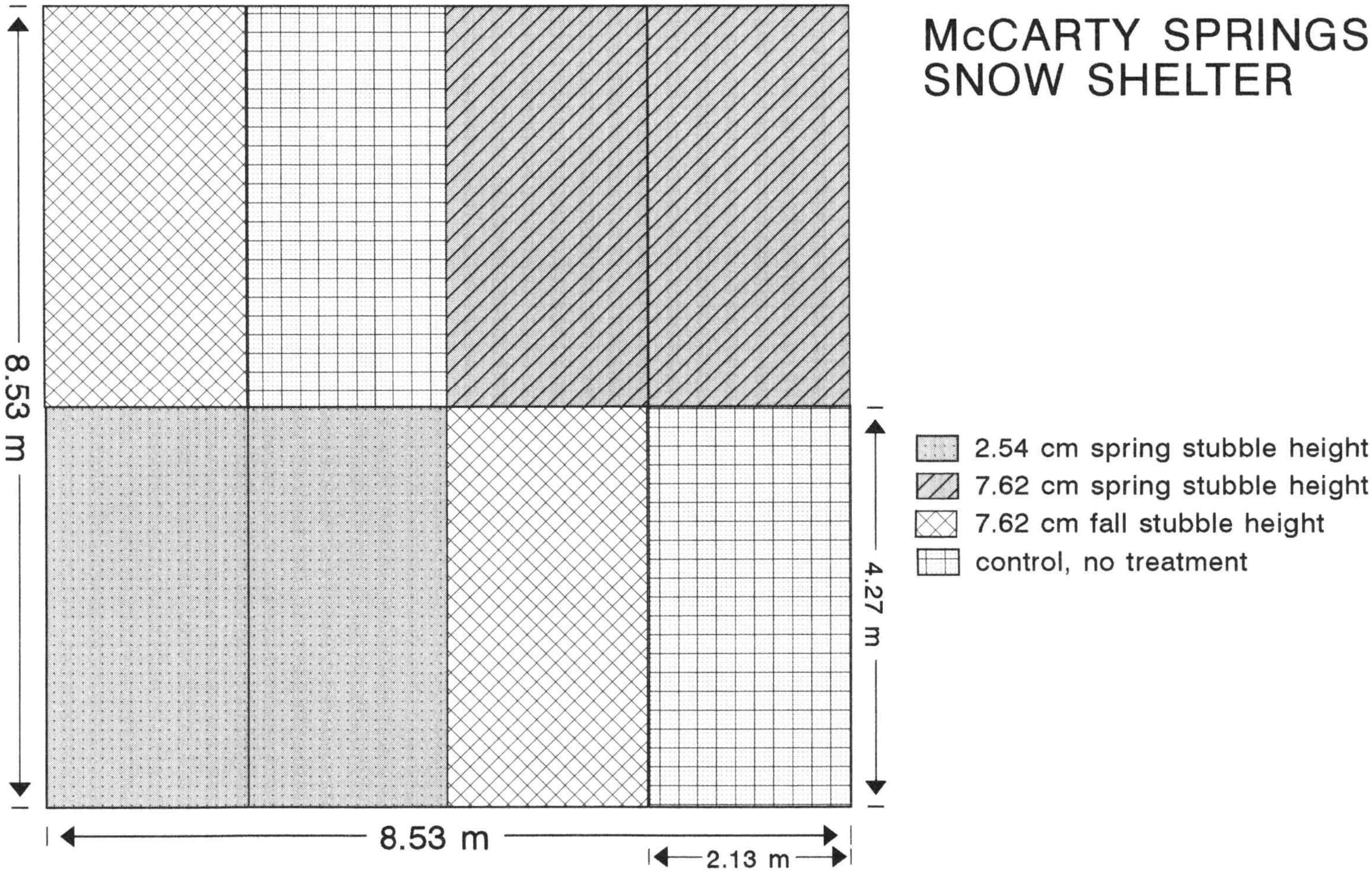

Figure 7. The McCarty Springs Snow Shelter Study Plots.

Vegetation Treatments

Treatment 1 was clipping of bluebunch wheatgrass to a 2.5 cm stubble height in the spring. Treatment 2 was the same as treatment one except that clipping was to a 7.6 cm stubble height. Both of these treatments were applied in mid- to late May right before the boot stage (Metcalfe 1973) of phenology. Treatment 3 was a clipping to a 7.6 cm stubble height in the fall (mid- to late September) following plant maturation but before rain stimulated fall growth. Treatment 4 was a control and no clipping of the vegetation was done. The same treatments were applied on all sites including plots under the snow shelters.

For analyses the treatment 4 vegetation material was divided into two categories. Treatment 4 refers to plant material which includes fall plant-growth material and treatment 5 will refer to plant-growth material which was summer-cured vegetation. This occurred because there was not a clear delineation in summer-cured vegetation in the fall of 1986. I was concerned that combining both plant materials might bias the results. Therefore, they were analyzed separately.

Sample Collection

Collection of samples started in October, following vegetation clipping treatments, and continued through March or early April. Vegetative-growth samples were collected from plants within the large plots when they were snow-free. Once snow covered the plants, samples were collected from plants inside the snow shelters until the plots were again snow-free outside the shelters. Samples were collected from all four treatments at each clipping interval.

Two types of plant growth were collected at each sampling -- the spring growth following spring treatments and fall-growth samples from all treatments. The spring-growth vegetation was cured from moisture and temperature stresses during the summer months (Figure 1). Fall growth was new leaf and tiller materials stimulated by late summer and early fall rains. Both spring-and fall-growth samples were collected to determine what the over-wintering processes of freezing, thawing, snow cover, and leaching had on nutrient contents of bluebunch wheatgrass available to deer and elk.

The sampling period corresponded with the time that elk would arrive and leave the winter range during an average year. By sampling at monthly intervals, the quality of that portion of the diet provided by bluebunch wheatgrass could be evaluated as winter progressed. Vegetation samples for nutrient content and digestibility for all treatments were collected by clipping the bluebunch wheatgrass plants down to a 2.5 cm stubble height.

In conjunction with the fall-clipping treatment in late September, plants from the plots not treated were collected and samples dissected into first leaf, second leaf, third leaf, inflorescence and culm (Figure 8) to determine the nutrient content of different plant appendages. Although seeds had fallen or been dispersed by this time, the remaining plant parts are what is available to wild ungulates during the winter months.

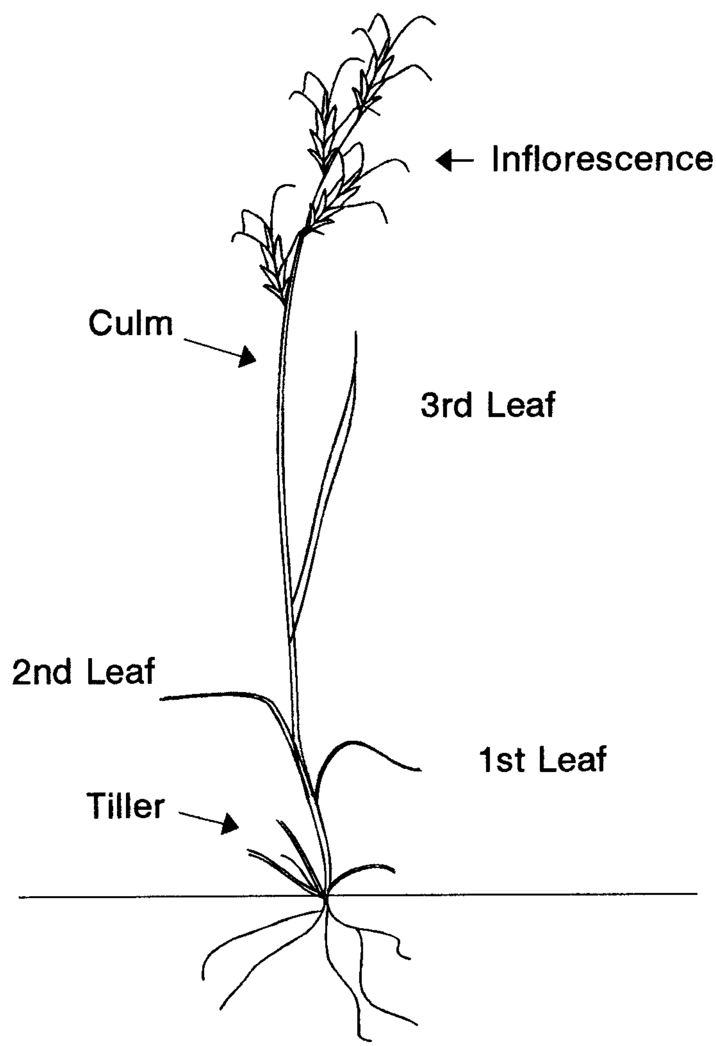

Figure 8. Computerized Diagram of a Bluebunch Wheatgrass Plant.

In October and April of each year, five random plots were selected from each treatment area and clipped to a 2.5 cm stubble height to determine the kg/ha dry matter of plant growth produced since treatment. This production would represent the quantity of available forage for grazing by elk during the winter. It is recognized that plant growth may continue later than October, depending on moisture and temperature fluctuations. However, this production was not measured.

All collected plant materials were oven-dried at 50^{o} C. for 24 hours and then weighed. After dry weights were attained, the samples were ground in a Wiley mill through a 40-mesh screen, placed in air-tight containers and stored until laboratory analysis occurred.

Laboratory Analysis

Chemical analysis of vegetation samples included determination of percent crude protein, *in vitro* dry matter digestibility (IVDMD), acid-detergent fiber (ADF), and lignin. The laboratory analysis for crude protein was the Kjeldahl method conducted in compliance with the Association of Official Analytical Chemists (AOAC 1980). A modification of the *in vitro* digestive technique of Tilley and Terry (1963) suggested by Warner (1983) was used to determine IVDMD. I recognized that rumen inoculum from wild ruminant ingestion may improve IVDMD data results (Campa III 1984). However, because of logistics in obtaining elk rumen inoculum the rumen inoculum used in the analysis was obtained from a fistulated steer fed on grass hay.

ADF and lignin were determined by the permanganate technique of Van Soest and Wine (1968). Digestible energy was calculated from an equation developed by Schommer (1978). The equation is as follows:

$$DE,\ Mcal/kg\ DM = 0.051\ (\text{ percent } DMD) - .7054$$

Rittenhouse et al. (1971) developed an equation using Great Plains plants, which should be applicable to other forage species (Holechek 1979). However, Schommer (1978) worked in central Washington in plant communities similar to those in eastern Oregon and included bluebunch wheatgrass. Therefore, I thought his calculations were more suitable for use in evaluation of plants from my study area.

Statistical Analysis

Levels of crude protein, IVDMD, ADF, and lignin were compared with respect to area, four treatments, months, and years by means of analysis of variance according to the methods set forth by Petersen (1985). Area was the blocking factor and year was a repeated measure of time. Where differences were observed, the Fisher's Protected Least Significant Difference (FPLSD) was used to compare treatment means. Levels of significance were tested at .05 ($P<0.05$). Standard errors and coefficient of variation were considered and are tabulated where applicable.

Westenskow (1991), who utilized the same study plots, tested slope effect on treatments with analysis of variance and compared differences with least mean squares (LSM) and found that slope was not a significant factor influencing the results. Therefore, I did not evaluate slope in these analyses. Significant interaction occurred, due, I believe, primarily to climatic differences (Tables 1 and 5) influencing the 1986 and 1987 data sets. Therefore, I analyzed the data for each year separately.

RESULTS AND DISCUSSION

Morphological Features

Crude Protein

My first objective was to determine, at plant maturity, the nutrient content and digestibility of these plant appendages: first leaf (oldest), second leaf, third leaf, inflorescence and culm (Figure 8). Plant material was collected for analysis when plant senescence occurred -- mid- to late September. The prehensile lips of deer and elk allow selection of specific plant appendages. Therefore, analysis of plant appendages available for grazing provides quality quantification of plant appendages as deer and elk forage during the winter.

The ANOVA examining differences in percent crude protein content indicated a difference ($P<.05$) between plant appendages and whole plants for both 1986 and 1987. The highest crude protein was found in the third leaf which was the youngest plant material (Table 7). FPLSD mean analysis was used to rank means (Table 8). Data were consistent between years with the older and structural plant material having less crude protein than leaf material. This follows Skovlin's (1967) hypothesis that leaves contained more crude protein than seedstalks. Cook and Harris (1950) reported crude protein content in grasses during the summer in Utah of 3.9 percent for culms, 12.3 percent in leaves and 6.2 percent for whole plants. These higher values are probably due to their collection before plant maturation.

Table 7. Mean Percent Crude Protein for Morphological Appendages in September 1986 and 1987.

	First Leaf	Second Leaf	Third Leaf	Inflorescence	Culm	Whole Plant
1986	3.88	4.24	4.32	2.69	3.17	3.48
1987	4.26	4.22	4.30	2.87	2.88	3.36

S.E. for 1986 was .20 and .13 for 1987 n=6/appendage
C.V. in 1986 was 13 percent, and 2 percent in 1987.

Table 8. FPLSD Mean Comparison of Crude Protein for Morphological Appendages in 1986 and 1987.

	Inflorescence	Culm	Whole Plant	First Leaf	Second Leaf	Third Leaf
1986	2.69	3.17	3.48	3.88	4.24	4.32

S.E. = .20 n= 6/Appendage
C.V. = 13 percent

	Inflorescence	Culm	Whole Plant	First Leaf	Second Leaf	Third Leaf
1987	2.87	2.88	3.36	4.22	4.26	4.30

S.E. = .13 n= 6/Appendage
C.V. 2 percent

The means which are underlined are not significantly (P<.05) different.

Dry Matter Digestibility

DMD was different ($P<.05$) between plant appendages in both years. The third leaf had the highest percentage of DMD while the inforescence had the lowest (Table 9). FPLSD ranked means are presented in Table 10. Although patterns were similar, there were major differences between years. Due to August and September rains in 1986 that did not occur in 1987 (Table 5), there was increased plant-moisture content in conjunction with more leaf material which probably increased this value. In 1987, which was drier during the summer months than 1986, (Table 5), the DMD value of whole-plant material was about mid-range between leaf material and structural material. The older or longer-exposed plant tissue to climatic conditions had a lower DMD value than younger material.

This effect is probably due to both drying conditions and translocation of nutrients from older to younger plant material. The 46.16 percent DMD values for whole plants in 1986 are comparable to the 46.5 percent reported by Svejcar and Vavra (1985) during late July in the Blue Mountains. The 34.16 percent DMD value of whole-plant material in 1987 is substantially less than the 1986 value and that presented by Svejcar and Vavra (1985). These lower DMD values for 1987 may have been influenced by the drier climatic conditions.

Table 9. Mean Percent DMD for Morphological Appendages in September of 1986 and 1987.

	First Leaf	Second Leaf	Third Leaf	Inflorescence	Culm	Whole Plant
1986	41.73	45.73	46.16	31.88	40.72	46.16
1987	40.25	43.58	43.58	29.14	29.42	34.16

S.E. for 1986 was 1.49 and 2.97 for 1987 n=6/Appendage
C.V. n 1986 was 8 percent, and 14 percent in 1987.

Table 10. FPLSD Mean Comparison for DMD for Morphological Appendages in September of 1986 and 1987.

	Inflorescence	Culm	First Leaf	Second Leaf	Whole Plant	Third Leaf
1986	31.88	40.72	41.73	45.73	46.16	46.16

S.E. = 1.49 n=6/Appendage
C.V. = 8 percent

	Inflorescence	Culm	Whole Plant	First Leaf	Second Leaf	Third Leaf
1987	29.14	29.42	34.16	40.25	43.48	43.58

S.E. = 2.97 n=6/Appendage
C.V. = 14 percent

The means which are underlined are not significantly (P<.05) different.

Acid Detergent Fiber

Collecting plant appendages of adequate quantities for all nutrient content analysis in replication exceeded available time. As a result, only enough material for ADF and lignin analysis was collected from two study areas in 1986 and one study area in 1987. ANOVA was calculated for both ADF and lignin on 1986 data but not on the 1987 data because enough material was collected only from one study site. However, the values for both ADF and lignin are tabulated and presented in Tables 11 and 13 respectively for information only.

ADF values between plant appendages were different ($P<.05$). The culm had the lowest value (37.5 percent) of ADF and the first leaf the highest value (44.8 percent). FPLSD indicates a difference ($P<.05$), however, the spread between means was small (Table 12). The ADF value of 40.53 percent for whole plants (Table 11) is lower than the 52 percent presented by Pitt (1986) for weathered bluebunch wheatgrass plants in southwest British Columbia. The small sample size (n=12) could be responsible for the lower and erratic data results. ADF is sometimes difficult to interpret because of summation of different entities which may be highly variable in their own digestibility (Holechek 1979).

Table 11. Mean Percent ADF for Morphological Appendages in September of 1986.

Culm	Third Leaf	Whole Plant	Second Leaf	Inflorescence	First Leaf
37.51	39.88	40.53	40.87	44.35	44.76

S.E. = .77 n=4/Appendages
C.V. = 2.5 percent

Table 12. FPLSD Mean Comparison of Percent ADF for Morphological Appendages in 1986.

Culm	Third Leaf	Whole Plant	Second Leaf	Inflorescence	First Leaf
37.51	39.88	40.53	40.87	44.35	44.76

S.E. = .77 n=4/Appendage
C.V. = 2.5 percent

The means which are underlined are not significantly (P<.05) different.

Lignin

Lignin values between plant appendages were not different (P>.05) in 1986. Results indicate the younger plant material had a lower percent lignin and then increased with time of exposure and structural material (Table 13). The leaf value was 2.98 percent lignin and the culm had 5.86 percent. These values are lower than reported from esophageal fistulated cattle by Holechek (1979) which was 10.4 percent for pooled vegetation data on grasslands in late spring on an adjacent research area.

Table 13. Percent Lignin for Morphological Appendages in 1986 and 1987.

	First Leaf	Second Leaf	Third Leaf	Inflorescence	Culm	Whole Plant
1986	3.96	3.84	2.98	5.58	5.86	4.80
1987	4.05	3.77	3.42	4.83	7.26	4.79

S.E. = .79 for 1986 n=4/Appendage
C.V. = 24 percent

Digestible Energy

Digestible energy (DE) conversion (Table 14) indicated a difference (P<.05) existed between years; there was also a difference (P<.05) between plant appendages in DE, Mcal/kg DM. Using data calculated from Schommer's (1978) procedure, there is a difference of 730 Kcal/kg DM for 1986 and 740 Kcal/kg DM for 1987 from the inflorescences and third leaf. Thus it would be advantageous for ungulate animals to select the leaf plant appendages, especially if quality drops below 50 percent DMD. When DMD ranges between 29.14 and 46.16 percent, the lower value could be termed a submaintenance level. Hobbs et al. (1981) reported a similar condition in Colorado.

Table 14. Conversion of Dry Matter Digestion to DE, Mcal/Kg DM for Plant Appendages for 1986 and 1987 after Schommer (1978).

	1986	1987
Inflorescence	.92	.78
Culm	1.37	.80
First Leaf	1.42	1.35
Second Leaf	1.63	1.51
Third Leaf	1.65	1.52

Conclusions

The null hypothesis that there are no differences between plant parts in their nutrient content or digestibility after plant maturation, is rejected. The alternate hypothesis is selected because differences occurred in nutrient content and digestibility between morphological appendages and whole plants.

Clipping Effects on Nutrient Content

Crude Protein

The first intent was to evaluate the nutrient contents of growth from clipped vegetation through the winter months to determine over-wintering effects on nutrient content. The second was to evaluate the differences in nutrient content between treatments through the winter months.

I could uncover no information on nutrient content of bluebunch wheatgrass from either cured vegetation or fall growth through the winter months. Pitt (1986) evaluated the nutrient content of growth on bluebunch wheatgrass plants following clipping of plants at different phenological stages in late spring and early summer, however, he ended the evaluation in October. Skovlin (1967) reported a decrease in crude protein in bluebunch wheatgrass from about 8 percent in July to 4 percent in October in the Blue Mountains.

Also in the Blue Mountains, Svejcar and Vavra (1985) reported a change of crude protein in bluebunch wheatgrass from a high of 19.3 percent in late April to 6 percent in late July. Anderson and Scherzinger (1975) hypothesized that once growth had been interrupted by grazing the nutrient content would be fixed in the plant and plants would retain higher nutrient content than plants which where not grazed. They also hypothesized that when plant growth is terminated by either heat or drought conditions, the palatability increases because of the conversion of starch to sugars. Fall-growth production can vary considerably between location (Quinton et al. 1982) and years and is usually initiated with precipitation during late summer and early fall (Skovlin 1967, Nowak and Caldwell 1984). Although fall growth has been identified as high quality forage when it occurs, quality and quantity values have not been documented. However, from the standpoint of managing wild ruminants, this vegetation could significantly influence winter survival rates.

There were differences ($P<.05$) in nutrient content between months, treatment and years. Because of differences between years, each year was analyzed separately. I believe the difference ($P<.05$) in nutrient content between years can be attributed to greater amounts of precipitation in August, September and October (Table 5) during 1986 than in 1987.

In 1986, the percent crude protein in October was different ($P<.05$) between treatments. The plants not clipped (Treatment 5) had the lowest value at 3.30 percent crude protein while the growth from the 7.6 cm fall-clipped plants had the highest value at 22.84

percent. The mean values of crude protein and separation of mean with FPLSD analyses for October are presented in Table 15. The mean value for the vegetation not clipped (Treatment 5) had the lowest value across months. Crude protein values from treatment 5 continued to decline (Table 16) through December (Table 17) and then increased back to original value by April (Table 18).

Table 15. FPLSD Mean Comparison of Crude Protein Across Blocks by Treatments for October 1986 and 1987.

Treatment	5	4	2	1	3
1986	3.30	14.14	14.49	15.81	22.84

S.E. = .98 n=12/Treatment
C.V. = 24 percent

Treatment	5	2	1
1987	3.57	4.00	5.73

S.E. = .26 n=12/Treatment
C.V. = 21 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 16. FPLSD Mean Comparison of Crude Protein Across Blocks by Treatments for November 1986 and 1987.

Treatment	5	1	3	2	4
1986	3.32	19.58	20.20	20.46	21.08

S.E. = .46 n=12/Treatment
C.V. = 8 percent

Treatment	5	2	1
1987	3.49	3.89	4.70

S.E. = .15 n=12/Treatment
C.V. = 14 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 17. FPLSD Mean Comparison of Crude Protein Across Blocks by Treatments for December 1986 and 1987.

Treatment	5	3	1	2	4
1986	3.04	15.13	15.15	15.70	16.23

S.E. = .61 n=4/Treatment
C.V. = 9 percent

Treatment	5	2	1
1987	3.36	3.84	4.79

S.E. = .16 n=6/Treatment
C.V. = 26 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 18. FPLSD Mean Comparison of Crude Protein Across Blocks by Treatment for March and April 1987 and 1988.

Treatment	5	4	1	2	3
1987-April	3.53	18.23	18.80	19.08	19.26

S.E. = .43 n=12/Treatment
C.V. = 9 percent

Treatment	5	2	1	3	4
1988-March	3.35	4.50	5.38	9.92	20.67

S.E. = 1.10 n=12/Treatment
C.V. = 44 percent

Treatment	5	2	4	1	3
1988-April	2.92	18.91	19.32	19.42	19.61

S.E. = .36 n=12/Treatment
C.V. = 8 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Statistical analysis of crude protein was conducted between years on cured vegetation (Treatment 5) and data indicated there were no differences (P>.05) between years. The highest crude protein value for cured vegetation (Treatment 5) was 3.57 percent in October 1986 (Table 15) and the lowest crude protein value of cured vegetation (Treatment 5) was 2.92 percent in April 1988 (Table 18). These data values of crude protein indicate a continual loss of crude protein in cured vegetation from October into early April. This trend was evident in both years (Tables 15, 18).

The crude protein content in the plant growth following the fall-clipped vegetation (Treatment 3) had the highest crude protein content for both years and between treatments at 22.84 percent (Table 15) in 1986. Crude protein values for this treatment dropped to 20.2 percent in November 1986. In December 1986, the crude protein content for this treatment dropped to 15.13 percent - a 25 percent decline in value from the November value. However, this was the lowest crude protein value recorded for this treatment during the 1986-87 winter period. In April, the crude protein content in this treatment was back up to 19.26 percent and this was the highest crude protein value of all treatments (Table 18) at this time. FPLSD mean comparison indicated that crude protein content from the plant growth following the fall-clipped (Treatment 3) vegetation was different (P<.05) from plant material analyzed in all other treatments in October 1986. The FPLSD mean comparison of crude protein values indicated no difference (P>.05), existed between treatments 1, 2, 3, and 4 in November, December, 1986 and April

1987. Crude protein content in the cured vegetation (Treatment 5) however, was different (P<.05) from all other treatments.

There was no vegetative growth following the fall clipping (Treatment 3) for analysis in the 1987-88 winter until March and April 1988. In March, the growth from the fall-clipped (Treatment 3) vegetation had 9.92 percent crude protein (Table 18) which was the second highest value of all treatments. FPLSD mean separation indicated a difference (P<.05) existed between crude protein content of the fall-clipped vegetation and all other treatments for March 1988. In April, however, with the exception of cured vegetation (Treatment 5) which was different (P<.05)from all other treatments, there were no differences (P>.05) existing between treatments 1, 2, 3, and 4 in crude protein content which ranged from 18.91 percent to 19.61 percent across treatments (Table 18).

The crude protein content from vegetation produced after the spring clipping to both a 2.5 cm (Treatment 1) and 7.6 cm (Treatment 2) just before the boot stage yielded similar results (Tables 15, 16, 17, and 18) in 1986. Crude protein values in October following the spring-clipping treatment were 15.81 percent and 14.49 percent respectively. FPLSD mean comparison (Table 15) indicated a difference (P<.05) existed in crude protein content of plant-growth material in October 1986 following the spring clipping of both the cured vegetation (Treatment 5) and fall-growth (Treatment 3) plant material. Although there was an increase of crude protein to 20.46 percent and 19.52 percent respectively in November, a 25 percent decrease in crude protein content followed in December with a 20 percent increase in value in April. The FPLSD mean comparison indicates no difference (P>.05) existed in crude protein content between treatments 1, 2, and 3 during the November, December and April samples of 1986-87. In 1987, FPLSD mean comparison indicates no difference (P>.05) existed between crude protein content (Tables 15 and 16) of growth material analyzed from the 7.6 cm spring-clipped (Treatment 2) vegetation and the cured vegetation (Treatment 5). Plant-growth material in October and November from the 2.5 cm spring-clipped (Treatment 1) vegetation was different (P<.05) from cured vegetation (Treatment 5) and plant growth from the 7.6 cm (Treatment 2) spring-clipped vegetation. However, FPLSD mean comparison indicated no difference (P>.05) existed in crude protein content between these two treatments in December 1987, March 1988 and April 1988 (Tables 16, 17, and 18). Even though no differences existed in percent crude protein content between these two treatments in December and March, growth following the 2.5 cm spring clipping had a 20-40 percent higher crude protein value (Table 15) than treatments 2 and 5.

Crude protein content in the vegetation not clipped (Treatment 4) was different (P<.05) from the crude protein content found in both the cured vegetation (Treatment 5) and fall-growth (Treatment 3) plant material in 1986. FPLSD mean comparison indicated (Table 15) a difference (P<.05) existed in crude protein content between this treatment and the cured vegetation (Treatment 5) and fall plant-growth material (Treatment 3). However, no differences (P>.05) existed in crude protein content between the two spring-clipped vegetation treatments (Treatments 1 and 2) (Tables 15, 16, 17, and 18) and this treatment in 1986. In 1987, only a trace of precipitation occurred (Table 5) during the August to October time period. Therefore, no fall plant growth was initiated or collected for analysis until March of 1988. Crude protein in unclipped vegetation (Treatment 4), during the March 1988 sampling, was different ($P<.05$) from all other treatments. In fact, the 20.67 percent crude protein (Table 18) from this treatment had more than twice the value of all other treatments. In April 1988, only the crude protein content from the cured vegetation (Treatment 5) was different ($P<.05$) than all other treatment values. FPLSD mean comparison indicated no difference ($P>.05$) existed in crude protein content for April between treatments 1, 2, 3, and 4 (Table 18).

Following the 8+ cm of precipitation in August through October, 1986, most of the spring-clipped plants (Treatment 1 and 2) and some plants which were not conditioned (Treatment 4) greened-up at the base of lower leaves and culm after summer senescence. I could not find a reference to or documentation of this phenomenon in the literature. I think this partially explains why the 14 percent plus crude protein content values occurred for plant material collected from all treatments except cured vegetation (Treatment 5) in the winter of 1986-87.

Because this "greening-up" of plant tissue affected crude protein content in 1986-87, I think the 1987-88 crude protein values provide a better understanding of how moisture and temperature stresses influence nutrient content of spring-clipped bluebunch wheatgrass versus plant tissue not clipped. This is what Anderson and Scherzinger (1975) hypothesized would increase the nutrient quality of forage available to wintering populations of big game.

Although there was a 1.5-2.0 percent greater concentration of crude protein in the spring-clipped vegetation over plants not clipped, only the 5.7 percent crude protein content in the 2.5 cm spring-clipped plants in October 1987 approximated the 5.7 percent crude protein needed for elk maintenance (Nelson & Leege 1982).

Dry Matter Digestibility

Dry matter digestibility (DMD) differed significantly ($P<.05$) between treatments by months (Tables 19, 20, 21, 22, and 23). In October, the clipping of vegetation to a 7.6 cm stubble height (Treatment 3), during September had the highest mean value (79.41 percent) for percent DMD (Table 19), and the cured vegetation from plants not clipped had the lowest value (38.44 percent) (Table 19). The cured vegetation (Treatment 5), with one exception in December 1986, lost DMD value every month. After October 1986, there were less than 15 percent differences in DMD between treatments. Again, I believe this was due predominantly to fall moisture (Table 5) and warm temperatures (Table 1) which produced more than 10 Kg/ha (Table 43) of fall growth. The ratio of spring-growth to fall-growth plant material from the spring treatment also elevated the percentage of DMD values. Percentages of DMD in 1986 which ranged from 33-83 percent across all treatments approximate the 32-87 percent DMD that Westenskow (1991) reported from the same area in 1988 and 1989.

Only trace precipitation (Table 5) in 1987 produced a different result. The 7.6 cm spring clipping (Treatment 1) had the highest percent DMD value of all treatments at 44.47 percent in October

(Table 2) and steadily decreased in value through December and into March 1988 (Table 22) at which time spring growth was initiated.

Table 19. FPLSD Mean Comparison of DMD Across Blocks by Treatments for October 1986 and 1987.

Treatment	5	4	2	1	3
1986	38.44	66.16	69.10	71.85	79.41

S.E. = 2.12 n=12/Treatment
C.V. = 12 percent

Treatment	2	5	1
1987	37.38	37.83	44.47

S.E. = 1.61 n=12/Treatment
C.V. = 14 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 20. FPLSD Mean Comparison of DMD Across Blocks by Treatments for November 1986 and 1987.

Treatment	5	1	3	2	4
1986	36.17	79.11	79.19	79.27	79.32

S.E. = 1.26 n=12/Treatment
C.V. = 6 percent

Treatment	2	5	1
1987	35.16	35.36	42.13

S.E. = 1.67 n=12/Treatment
C.V. 16 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 21. FPLSD Mean Comparison of DMD Across Blocks by Treatments for December 1986 and 1987.

Treatment	5	4	3	2	1
1986	36.61	69.30	77.35	80.46	84.20

S.E. = 6.17 n=4/Treatment
C.V. = 18 percent

There were no significant (P<.05) differences between treatment in December 1987. The following values are for comparison only.

Treatment	5	2	1
1987	32.14	32.45	33.65

No Significant Difference (P=.23)

S.E. = 1.76 n=6/Treatment
C.V. = 13 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 22. FPSLD Mean Comparison of DMD by Blocks by Treatments for March 1988.

Treatment	5	2	1	3	4
1988	22.73	29.32	31.64	48.04	82.59

S.E. = 3.75 n=12/Treatment
C.V. = 30 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 23. FPLSD Mean Comparison of DMD Across Blocks by Treatments for April 1987 and 1988.

Treatment	5	4	2	3	1
1987	33.57	79.82	80.32	80.48	83.24

S.E. = 1.04 n=12/Treatment
C.V. = 5 percent

Treatment	5	3	4	1	2
1988	26.25	63.96	63.98	64.59	64.95

S.E. = .72 n=12/Treatment
C.V. = 4 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
- 1= 2.5 cm spring clipping, growth after clipping
- 2= 7.6 cm spring clipping, growth after clipping
- 3= 7.6 cm fall clipping, fall growth
- 4= Control (not clipped) fall-growth vegetation
- 5= Control (not clipped), cured vegetation

There was a significant (P<.05) difference between treatments with treatments 5 and 2 slightly different from treatment 1 (Tables 19, 20, 21, 22, and 23) through October and November. After that time, no statistical difference existed between the three treatments. Treatments 3 and 4 are not listed in the results because no fall growth was produced for sampling. With respect to Anderson and Scherzinger's (1975) hypothesis that forage quality would be improved by clipping or grazing the plants in the spring the DMD from both spring treatments (treatments 1 and 2), which were conditioned simultaneously, were not significantly (P<.05) different from the plants not clipped. However, by April, although not statistically different, the two spring-treatment plants had the highest percentage of DMD (Table 23).

Acid Detergent Fiber

Analysis for ADF and lignin was only conducted on vegetation from the McCarty Springs area. There were significant (P<.05) differences between treatments (Tables 24, 25, 26 and 27) and months (Table 28) in both sampling periods of 1986-87 and 1987-88. In October 1986 there was a 7.2 percent difference in ADF between treatments 1 through 3 with a 23 percent difference in ADF content between treatment 3 and treatment 5 (Table 24).

In April of 1988, treatment 5 had the highest (47.23 percent) percentage of ADF of all treatments in both years (Table 27) and treatment 1 in December 1986 had the lowest (16.17 percent)(Table 26). The cured vegetation (Treatment 5) ADF values of 36.91-47.23

percent are a very close approximation with the 37.9-49.8 percent ADF reported by Pitt (1986) for cured bluebunch wheatgrass plants. In 1987, the same situation existed as in 1986. The major difference, however, was the increased percentage of ADF in treatment 1 and 2. In fact, there was less than 2 percent ADF content difference between the plant material from the clipped and those plants not clipped (Table 28) until plant growth was initiated in March (Table 26).

Table 24. FPLSD Mean Comparison of ADF for McCarty Springs by Treatments for October 1986 and 1987.

Treatment	3	1	2	4	5
1986	18.59	23.94	25.79	32.01	42.10

S.E. = 2.74 n=4/Treatment
C.V. = 19 percent

Treatment	1	2	5
1987	35.47	35.59	36.91

S.E. = .36
C.V. = 2 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 25. FPLSD Mean Comparison of ADF for McCarty Springs by Treatments for November 1986 and 1987.

Treatment	3	2	4	1	5
1986	18.45	19.06	19.13	19.98	44.24

S.E. = .75
C.V. = 6 percent

Treatment	1	2	5
1987	40.23	40.48	42.10

S.E. = .40 n=4/Treatment
C.V. = 2 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
- 1= 2.5 cm spring clipping, growth after clipping
- 2= 7.6 cm spring clipping, growth after clipping
- 3= 7.6 cm fall clipping, fall growth
- 4= Control (not clipped) fall-growth vegetation
- 5= Control (not clipped), cured vegetation

Table 26. FPLSD Mean Comparison of ADF for McCarty Springs by Treatments for December 1986 and 1987.

Treatment	1	4	2	3	5
1986	16.17	16.59	17.18	18.28	45.04

S.E. = 1.50 n=2/Treatment
C.V. = 10 percent

Treatment	1	2	5
1987	40.09	40.55	40.66
	No Significant Difference (P=.82)		

S.E. = .45 n=2/treatment
C.V. = 1.6 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 27. FPLSD Mean Comparison of ADF for McCarty Springs by Treatments for March and April 1987 and 1988.

Treatment	4	3	2	1	5
1987-April	20.63	21.84	22.67	24.57	46.10

S.E. = 1.56 n=4/Treatment
C.V. = 11 percent

Treatment	1	2	3	5
1988-March	43.72	45.31	45.58	46.37

S.E. = .66 n=4/treatment
C.V. = 3 percent

Treatment	1	2	3	4	5
1988-April	22.47	22.66	23.17	23.58	47.23

S.E. = .44 n=4/treatment
C.V. = 3 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 28. FPLSD Mean Comparison of ADF Across Months for 1986-87 and 1987-88.

	Dec.	Nov.	Mar.	Oct.
1986-87	22.65	23.99	27.16	28.49

S.E. = .96 n=70
C.V. 17 percent

	Apr.-88	Oct.-87	Dec.-87	Nov.-87	Feb.-88	Mar.-88
1987-88	28.20	34.41	38.80	39.17	43.23	44.57

S.E. = 1.05 n=88
C.V. = 11 percent

The means which are underlined are not significantly (P<.05) different.

Lignin

Lignin concentrations were not different (P>.05) between months in 1986 but were different (P<.05) in 1987 (Table 29). However, there were monthly differences (P<.05) between treatments in both years (Tables 30, 31, 32 and 33). The highest concentration of lignin was found in plants not clipped with 7.81 percent in March 1988 (Table 33) and lowest in fall growth (Treatment 3) with a mean of 1.08 percent in October 1986.

The 1987-88 concentrations of lignin were higher than was found in 1986 (Table 29). In March 1988, the lowest percentage found was 6.20 percent and the highest was 7.81 percent (Table 33). By April 1988, the cured vegetation (Treatment 5) had the highest lignin value with 6.19 percent and treatment 4 the lowest value of 1.97 percent. The primary difference between years was the result of no fall growth during the fall and winter of 1987-88. The highest lignin value of clipped plants in 1986-87 was 2.39 percent (Table 30), almost equal to the lowest lignin value of 2.33 percent in April 1987-88 (Table 33).

Table 29. FPLSD Mean Comparison of Lignin Across Months for 1986-87 and 1987-88

	Dec.-86	Nov.-86	Apr.-87	Oct.-86
1986-87	2.30	2.59	3.17	3.58

No Significant Difference (P=.33)

S.E. 2.46 n=70
C.V. = 72 percent

	Apr.-88	Dec.-87	Oct.-87	Nov.-87	Feb.-88	Mar.-88
1987-88	3.12	3.71	3.82	4.01	5.37	6.72

S.E. = .23 n=88
C.V. = 20 percent

The means which are underlined are not significantly (P<.05) different.

Table 30. FPLSD Mean Comparison of Lignin for McCarty Springs by Treatments for October 1986 and 1987.

Treatment	3	1	2	5	4
1986	1.08	1.93	2.39	5.08	5.35

No Significant Difference (P=.154)

S.E. = 1.38 n=4/Treatment
C.V. = 87 percent

Treatment	1	2	5
1987	3.59	3.71	4.15

No Significant Difference (P=.28)

S.E. = .24 n=4/treatment
C.V. = 13 percent

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 31. FPLSD Mean Comparison of Lignin for McCarty Springs by Treatments for November 1986 and 1987.

Treatment	4	3	2	1	5
1986	1.49	1.63	1.85	2.04	6.11

S.E. = .32 n=4/Treatment
C.V. = 24 percent

Treatment	1	2	5
1987	3.37	3.91	4.35

S.E. = .23 n=4/treatment
C.V. = 11 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 32. FPLSD Mean Comparison of Lignin for McCarty Springs by Treatments for December 1986 and 1987.

Treatment	2	4	3	1	5
1986	1.21	1.23	1.38	1.98	5.70

S.E. = .37 n=2/Treatment
C.V. = 23 percent

Treatment	1	2	5
1987	3.76	3.79	4.06

No Significant Difference (P=.15)

S.E. = .16 n=2/treatment
C.V. = 5 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 33. FPLSD Mean Comparison of Lignin for McCarty Springs by Treatments for March and April 1987 and 1988.

Treatment	4	2	3	1	5
1987-April	1.71	2.32	2.38	4.69	6.77

S.E. = 1.22 n=4/Treatment
C.V. = 68 percent

Treatment	5	1	2	3
1988-March	6.20	6.40	6.48	7.81

S.E. = .20 n=4/treatment
C.V. = 6 percent

Treatment	4	1	3	2	5
1988-April	1.97	2.03	2.05	2.21	6.19

S.E. = .22 n=4/treatment
C.V. = 15 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Conclusions

The conclusions reached were determined as follows. The first hypothesis tested was that no difference existed in nutrient content or digestibility of fall growth by month between October and March. This null hypothesis was rejected and the alternative selected. This determination was based on only 1986-87 data. There was no fall growth during the fall of 1987-88. There were significant differences in three of four nutrient content analyses conducted. DMD was not different ($P>.05$) between months and the average for all four months was 79.32 percent. Crude protein, ADF and lignin levels were all different ($P<.05$) between months. Crude protein averaged 20.18 percent, ADF averaged 19.60 percent and lignin averaged 1.66 percent for all four months. Crude protein and DMD values this high indicate a very high quality forage. The changing of nutrient content through the winter does not appear to be as severe as nutrient losses from temperature and moisture stresses during the summer - which have been documented in the literature.

The second hypothesis was that no difference existed in nutrient content or digestibility of fall growth between treatments. This hypothesis was rejected as differences ($P<.05$) did exist between treatments of fall growth. Again, this is based only on 1986-87 data because fall growth did not occur during the 1987-88 sampling period. Although there were differences ($P<.05$) between treatments, in nutrient content most occurred during October and November, followed by a leveling of values so that no differences occurred during December and April. The primary difference occurred with crude protein and DMD in treatment 3 (plants clipped to 7.6 cm stubble height in fall) responding faster, I believe, to fall precipitation (Table 5) and warmer weather (Table 1) than the other treatments.

Comparison of Growth Forms

My third objective was to determine if a difference existed in nutrient content and digestibility between plant morphological appendages and fall-growth plant material. The hypothesis was that no differences in nutrient content or digestibility occurred between morphological appendages and fall growth through the freezing and thawing months of winter. Fall growth did not materialize during the 1987-88 sampling period, so results are based only on 1986-87 data. There was a difference ($P<.05$) in nutrient content and digestibility between all plant appendages and fall-growth (Treatment 3) plant material. Crude protein values of 20.18 percent for fall growth were four times greater than the highest plant appendage crude protein value of 4.32 percent. Dry matter digestibility values (80.48 percent) of fall-growth (Treatment 3) plant material were almost twice the plant appendage values (46.16 percent third leaf). ADF and lignin values for plant appendages (ADF 39.88 percent, lignin 2.98 percent for third leaf) were substantially greater than fall-growth values of 21.84 percent ADF and 2.05 percent lignin after winter in March.

Comparison of Spring Treatments

Objective 4 was to determine if differences existed in nutrient content and digestibility between treatment 1 (vegetation clipped to a height of 2.5-cm in spring) and treatment 2 (vegetation clipped to a height of 7.62-cm in spring). The hypothesis tested was no difference existed between treatments in nutrient content or digestibility of spring-/summer-growth material. In 1986, there were no significant ($P>.05$) differences between treatments 1 and 2 during the four-month sampling period. However, during the 1987-88 sampling period, there were differences ($P<.05$) in nutrient content between treatments (Tables 15 and 20) as measured in crude protein and DMD. Treatment 1 was significantly ($P<.05$) higher in crude protein and DMD in October and November than treatment 2. From a practical aspect these were only minor differences. In treatment 1 for the example the crude protein was 5.73 percent in October and 4.70 percent in November, while treatment 2 had 4 percent crude protein in October and 3.89 percent in November. Based on these results and the influences of precipitation effects on the 1986-87 data, I think the 1987-88 data produced a more typical picture of how the two treatments compare in most years. The hypothesis was rejected and the alternative hypothesis accepted. However, I think from a practical viewpoint the nutrient content and digestibility parameters are essentially the same between treatments.

Comparison of Spring Treatments and No Treatment

Achievement of objective 5 required testing of two hypotheses. The first of these hypotheses was that there was no difference in nutrient content or digestibility between cured vegetation (Treatment 5) and spring/summer growth in treatments 1 and 2. The second hypothesis was that no difference existed between the summer-cured vegetation (Treatment 5) and fall-growth (Treatment 3) plant material in nutrient content or digestibility exposed to freezing and thawing from October through March. In both years, there were differences ($P<.05$) between spring treatments and the summer-cured vegetation. In the 1986-87 season there were differences (Tables 34, 35, 36 and 37) in nutrient content. However, there were lesser differences during the 1987-88 sampling period (Tables 16, 17, 18 and 19). In all months and treatments the nutrient content in cured vegetation (Treatment 5) had the absolute lowest crude protein and DMD values (Tables 16, 17, 34 and 35). Therefore, the first hypothesis was rejected and the alternative accepted as differences between spring treatments and cured vegetation existed.

The second hypothesis that no differences in nutrient content or digestibility existed in fall plant growth from clipping in the fall (Treatment 3) and cured plant material (Treatment 5) was also rejected. Differences ($P<.05$) existed in crude protein and DMD for every sampling month in 1986-87 between treatment 3 and 5. No comparison could be made during the 1987-88 sampling period because no fall growth of vegetation occurred. During the 1986-87 sampling, the crude protein of fall growth (Treatment 3) had analysis values (19+ percent) which were several times the values (3 percent) of cured vegetation (Treatment 5) (Table 15).

Table 34. FPLSD Mean Comparison of Crude Protein Between Treatments 1, 2 and 5 for October, November, December 1986 and April 1987.

Treatment	5	2	1
1986-October	3.30	14.49	15.78

S.E. = .89 n=12/Treatment
C.V. = 28 percent

Treatment	5	1	2
1986-November	3.32	19.57	20.42

S.E. = .44 n=12/treatment
C.V. = 11 percent

Treatment	5	1	2
1986-December	3.04	15.15	15.70

S.E. = .48 n=4/treatment
C.V. = 8 percent

Treatment	5	1	2
1987-April	3.53	18.80	19.08

S.E. = .43 n=12/treatment
C.V. = 11 percent

The means which are underlined are not significantly ($P<.05$) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 35. FPLSD Mean Comparison of DMD Between Treatments 1, 2 and 5 for October, November, December 1986 and April 1987.

Treatment	5	2	1
1986-October	38.44	69.10	71.87

S.E. = 2.05 n=12/Treatment
C.V. = 12 percent

Treatment	5	1	2
1986-November	36.17	79.07	79.22

S.E. = 1.29 n=12/treatment
C.V. = 7 percent

Treatment	5	1	2
1986-December	36.61	80.46	84.20

S.E. = 1.48 n=4/treatment
C.V. = 4 percent

Treatment	5	1	2
1987-April	33.57	80.32	83.24

S.E. = 1.25 n=12/treatment
C.V. = 7 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 36. FPLSD Mean Comparison of ADF Between Treatments 1, 2 and 5 for October, November, December 1986 and April 1987.

Treatment	1	2	5
1986-October	23.94	25.79	42.09

S.E. = 1.36 n=4/Treatment
C.V. = 9 percent

Treatment	2	1	5
1986-November	19.06	19.98	44.24

S.E. = .76 n=4/treatment
C.V. = 6 percent

Treatment	1	2	5
1986-December	16.17	17.18	45.04

S.E. = 1.93 n=2/treatment
C.V. = 11 percent

Treatment	2	1	5
1987-April	22.67	24.57	46.10

S.E. = 1.96 n=4/treatment
C.V. = 13 percent

The means which are underlined are not significantly ($P<.05$) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 37. FPLSD Mean Comparison of Lignin Between Treatments 1, 2 and 5 for October, November, December 1986 and April 1987.

Treatment	1	2	5
1986-October	1.93	2.39	5.08

S.E. = .37 n=4/Treatment
C.V. = 24 percent

Treatment	2	1	5
1986-November	1.85	2.04	6.11

S.E. = .33 n=4/treatment
C.V. = 20 percent

Treatment	2	1	5
1986-December	1.21	1.98	5.70

S.E. = .26 n=2/treatment
C.V. = 12 percent

Treatment	2	1	5
1987-April	2.33	4.69	6.77

S.E. = 1.55 n=4/treatment
C.V. = 67 percent

The means which are underlined are not significantly (P<.05) different.

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Comparison of Fall Growth and Cured Vegetation

The hypothesis tested for objective 6 was that no difference existed in nutrient content or digestibility of summer-cured vegetation (Treatment 5) between October and April. There were significant ($P<.05$) differences in both years between nutrient content in October and April. Crude protein values increased in 1986-87, but were not different ($P>.05$). In the 1987-88 period, crude protein started at 3.57 percent in October then decreased slightly to 2.92 percent in April. DMD values were different ($P<.05$) between October and April in both the 1986-87 and 1987-88 sampling periods. In both years, DMD decreased in value from October (38.44 percent in 1986 and 37.38 percent in 1987) to April (33.57 percent in 1987 and 26.25 percent in 1988). ADF and lignin values increased between October and April in both sampling periods and were different ($P<.05$) . Therefore, the hypothesis was rejected and the alternative selected as differences ($P<.05$) did exist between October and April. Overall the quality of cured vegetation declined through the winter.

Freezing and Thawing

The hypothesis tested for objective 7 was that no differences existed between nutrient content or digestibility between fall-growth vegetation (Treatment 3) exposed to freezing and thawing and fall growth (Treatment 3) which was covered with snow through the winter. The 1987 and 1988 fall-growth values were similar between treatments (Table 38), and major differences occurred between years. There was a difference (P<.05) in crude protein and ADF between treatments and no difference (P>.05) between treatments in DMD and lignin concentrations in 1987.

Although there are significant (P<.05) differences between treatments for DMD, ADF and lignin in 1988 these values may be erroneous because no fall growth occurred. Growth occurred under the snow and in the snow shelters. Therefore, only the raw data results are presented (Table 39). ANOVA indicated differences (P<.05) in nutrient content and digestibility, therefore, the hypothesis is rejected and the alternative accepted. However, from a practical aspect, it seems likely that differences in quality between plant material covered and not covered with snow and foraging selection by ruminants between treatments would be negligible. The results suggest the effects of freezing and thawing on plant tissue versus those plants insulated with snow is only marginal. The DE calculations for all treatments in the snow shelter are presented in Table 40.

Table 38. Mean Percent Crude Protein, DMD, ADF and Lignin Values for Both Snow-Covered and Not-Snow-Covered Fall Growth in April for 1987 and 1988.

	Snow Covered n=12	Not Snow Covered n=2
Crude Protein		
1987	19.03	19.91
1988	19.61	19.38
DMD		
1987	80.48	78.97
1988	63.96	60.40
ADF		
1987	21.84	25.33
1988	23.18	25.32
Lignin		
1987	2.38	2.61
1988	2.05	2.20

Table 39. Snow Shelter Data Summary for Crude Protein, DMD, ADF and Lignin by Treatments Across Months for 1987-1988.

Month / Treatment	Jan. 87	Jan. 88	Feb. 87	Feb. 88	Mar. 88	Apr. 87	Apr. 88
CRUDE PROTEIN							
1	18.09	5.31	15.73	5.10	5.15	19.06	16.87
2	19.28	4.91	18.61	4.55	4.55	20.19	21.54
3	17.55	NG	17.23	3.07	4.62	19.91	20.21
4	16.97	NG	17.25	NG	3.31	21.37	21.18
5	3.88	3.80	3.06	3.52	3.77	4.55	10.70
DMD							
1	84.49	35.93	76.75	50.28	41.78	82.13	61.01
2	83.09	38.25	77.96	51.74	37.57	79.93	60.40
3	81.75	NG	77.62	43.33	36.92	79.67	60.32
4	82.93	NG	81.60	NG	52.05	80.28	60.95
5	41.04	28.04	31.08	47.07	31.65	38.93	26.47
ADF							
1	18.32	39.05	21.20	41.44	37.68	38.38	21.83
2	20.69	40.34	21.17	42.27	39.51	36.54	20.52
3	20.21	NG	20.82	NG	41.34	37.02	20.89
4	19.62	NG	20.80	NG	25.88	36.06	NA
5	44.90	43.18	45.07	42.18	41.77	56.35	39.95
LIGNIN							
1	.29	3.50	2.53	3.57	3.24	5.17	6.41
2	1.74	3.40	1.80	3.87	3.17	4.59	6.49
3	1.51	NG	2.81	NG	6.86	5.04	NA
4	1.91	NG	2.85	NG	1.86	4.26	NA
5	5.21	4.56	5.67	4.43	6.51	9.08	10.11

NG=No Plant Growth NA=No Analysis

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Table 40. Digestible Energy (DE) Mcal/Kg DM Conversions of DMD from the Snow Shelters Using Schommer's (1978) Equation.

DE USING SCHOMMER'S (1978) EQUATION

DE, Mcal/Kg DM = .051 (percent DMD) - .7054

Treatment	Jan.87	Jan.88	Feb.87	Feb.88	Mar.88	Apr.87	Apr.88
1	3.60	1.13	3.21	1.86	1.43	3.48	2.41
2	3.53	1.25	3.27	1.93	1.21	3.37	2.38
3	3.46		3.25	1.50	1.18	3.36	2.37
4	3.52		3.46		1.95	3.39	2.40
5	1.39	.72	.88	1.70	.91	1.28	.65

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.6 cm spring clipping, growth after clipping
3= 7.6 cm fall clipping, fall growth
4= Control (not clipped) fall-growth vegetation
5= Control (not clipped), cured vegetation

Production

Spring and Summer

Objective 8 was to determine if spring-/summer-forage growth production was different between vegetation clipped in the spring and plants not clipped at maturity. The hypothesis was that no difference existed in forage production between the spring-clipping treatments. The sample size was (n=2 for treatment 1 and n=3 for treatment 2) too small to justify statistical analysis. However, means were calculated (Table 41). Spring treatments had the same weight value of Kg/ha DM, but production was only 76 percent of total production of vegetation not clipped.

Digestible Energy

Objective 9 was to determine digestible energy (DE) in Mcal/kg DM of plant material from all treatments where DMD was analyzed. I used Schommer's (1978) equation to calculate DE and these data are tabulated and presented in Table 42.

Fall Growth

Objective 10 was to determine production of fall growth in Kg/Ha from each treatment including vegetation not clipped. The sample sizes are small (n=6) due to small areas (150-200m^2) which were treated (Table 43). However two observations are quite apparent. First, fall-growth production is approximately 10 percent of plants not clipped (Table 43) in overall available biomass for foraging. Second, the production pattern by treatments was consistent between plots covered by snow shelters and plots not covered. The lowest production occurred on treatment 1 (the most severe treatment), and treatment 3 (the least severe) had the highest production.

Table 41. Mean Production for October in Kg/ha for Production of Spring Treatments (Treatments 1 and 2) in 1987.

Treatment	1	2	5
1987	134.4	134.4	176.96

n = 2 for treatment 1
n = 3 for treatment 2
n = 5 for treatment 5

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.62 cm spring clipping, growth after clipping
3= 7.62 cm fall clipping, fall growth
4= Control (unclipped) fall-growth vegetation
5= Control (unclipped), cured vegetation

Table 42. Conversion of DMD to DE, Mcal/Kg DM by Treatments Over Months using Schommer's (1978) Equation.

1986 Treatments	Oct.	Nov.	Dec.	April
1	2.02	2.30	2.49	2.46
2	1.92	2.31	2.35	2.35
3	2.31	2.30	2.23	2.35
4	1.81	2.31	1.93	2.33
5	.76	.67	.69	.57
1987				
1	.98	.90	.57	1.75
2	.72	.63	.53	1.76
3	NG	NG	NG	1.72
4	NG	NG	NG	1.73
5	.73	.64	.38	.29

NG= No plant growth

1/ Treatments:
1= 2.5 cm spring clipping, growth after clipping
2= 7.62 cm spring clipping, growth after clipping
3= 7.62 cm fall clipping, fall growth
4= Control (unclipped) fall-growth vegetation
5= Control (unclipped), cured vegetation

Table 43. Ranking of Bluebunch Wheatgrass Fall-Growth Production in Kg/ha DM for All Treatments Averaged Across Block for 1986 and 1987 in October.

Treatment	1	4	2	3	5
1986 n=6/Treatment	11.2	21.28	22.03	22.4	219
1987	No fall growth occurred				202 (n=12)

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.62 cm spring clipping, growth after clipping
3= 7.62 cm fall clipping, fall growth
4= Control (unclipped) fall-growth vegetation
5= Control (unclipped), cured vegetation

Table 44. Ranking of Fall-Growth Production for March in Kg/ha by Treatment from Inside the Snow Shelters for 1986.

Treatment	1	4	2	3
1986	24.12	48.62	50.4	78.6
n = 6 for each treatment				
1987	No fall growth occurred			

1/ Treatments:

1= 2.5 cm spring clipping, growth after clipping
2= 7.62 cm spring clipping, growth after clipping
3= 7.62 cm fall clipping, fall growth
4= Control (unclipped) fall-growth vegetation
5= Control (unclipped), cured vegetation

Fall growth produced by vegetation not clipped was lower than both spring treatments (1 and 2) and the fall treatment. This also occurred on the snow-shelter plots (Table 44). This appears to be contradictory to what Sauer (1978) reported for treated versus not-treated vegetation. He reported a 28 percent decline between clipped versus plants not clipped. This was not comparable to the work reported here as he did not specifically address growth after clipping and worked in an area receiving 20 cm of precipitation compared to the 50 cm (Table 5) received in this study area.

Fall-growth production figures are considerably less than those reported by Westenskow (1991) from the same area during 1989 when the area received 8.9 cm of precipitation during August through October. I collected data in October and she collected in November. With the moisture and warm temperatures in 1986, significant growth occurred after October but was not measured. However, within the larger plots (150-200m^2), when comparing the snow-shelter data sets which were collected in March with Westenskow's (1991) data collected in November, production figures are similar. So, significant growth did occur after October when moisture and temperature conditions were sufficient or similar to those which existed in 1986 (Table 2).

DISCUSSION

Winter Range Evaluation

Big game winter ranges by nature are often large and indistinct, poorly defined and lines of demarcation variable depending on winter severity. Because of these traits, the carrying capacity of these areas is difficult to calculate, assess or create and it is likewise difficult to implement management plans for multiple-use goals. Cover and forage are the two factors which need careful assessment when developing management plans for winter range areas. With increased demands for multiple resource uses, the current practice of drawing lines on maps encompassing large areas to define or delineate winter range areas is no longer acceptable practice. Many winter range areas are used by both livestock and big game populations. However, time of use is usually different by species with livestock using the areas for spring or fall range or both and big game using the same areas for winter range.

Setting stocking rates for proper use of vegetation to maintain or improve range conditions is an accepted range management practice on public lands. Stocking rates are intended to be conservative enough so they can be maintained year after year without impacting or inducing irreversible damage to either vegetation or related resources (Holechek et al. 1989). If conditions prevail where the potential exists for resource damage to occur from grazing, livestock can be manipulated to prevent such damage. Stocking rates on such ranges can be managed to leave a percentage of current year's forage production for big game use. Livestock can be manipulated to enhance winter range conditions that can optimize forage quantity and quality for wintering big game populations.

Although carrying capacity can, at least to some degree, be crudely calculated for big game winter ranges (Nelson 1982), the big game population manipulation necessary to maintain consistency within resource carrying capacity is difficult (Lyon and Ward 1982). There are a number of factors that make it difficult for managers to attain "proper" stocking levels. Public sentiment, in many cases, objects to large scale occurence of winter mortalities in big game herds, so artificial feeding programs are sometimes implemented, resulting in populations being maintained above natural carrying capacity.

Because of public philosophy that higher big game numbers are better, it is difficult for managers to regulate populations on the basis of the anticipated "worst" year. Fluctuating weather patterns and climatic conditions, while impossible to anticipate, allow populations to increase and decrease, and are also an important facet in development of management strategies for maintaining stable populations with biological surplus that can be harvested by hunters. Regardless of the effects of big game population manipulation, an improved method of delineating the winter range forage is sorely needed.

Nutritional Requirements of Wintering Elk

Maintenance requirements for pregnant wintering elk have not been determined. However, Nelson and Leege (1982) have estimated from other research and NRC (National Research Council) requirements for pregnant cattle that cow elk would require about 6,035 Kcal/day for basic metabolic rate plus activity. When temperature is $0^{\circ}C$, the daily non-fasting heat loss is approximately 5,342 Kcal (Westenskow 1991). By adding the maintenance requirements with heat loss, a 236 Kg cow elk would need 11,377 Kcal of metabolizable energy (ME) per day.

Crude protein requirements for white-tailed deer (_Odocoileus virginanus_) were estimated at 6-7 percent for growth and reproduction (French et al. 1955). Smith et al. (1975) found crude protein requirement for white-tailed deer fawns to be 19 gms of digestible crude protein per Kg of body weight. Nelson and Leege (1982) calculated the crude protein requirement for elk at 5.7 percent for maintenance and increased up to about 12 percent for maintenance and lactation following parturition.

DMD influences intake rates, digestion time and nutrient content of forages. Ammann (1973) and Hobbs et al. (1981) have suggested that when forages drop below 50 percent DMD, sufficient digestible energy is not available for animals to maintain basic energy requirements for maintenance. Forage intake of grazing ruminants on poor quality forages is usually controlled by rumen distention (Schwartz and Hobbs 1985, Moen 1973). Therefore, the lower the quality of forage, the longer the digestibility time becomes, and thus decreases forage intake (Schwartz and Hobbs 1985). This can affect winter survival rates of native ruminants during harsh winters (Ammann 1973, Nelson and Leege 1982). DMD of most grasses declines as maturation proceeds and can decline below 40 percent after fall maturity (Cook and Harris 1950; Holechek 1979; Westenskow 1991).

Crude protein concentration for spring treatments and control vegetation did not meet minimum requirements for elk after maturation. During the 1986 sampling period, there was 8+ cm precipitation in August through October which allowed the plants to "green-up". At that point, crude protein exceeded maintenance requirements with the exception of totally-cured vegetation which was only 3.29 percent crude protein. In 1987, treatment 1 vegetation met crude protein requirements in October and then declined below elk nutritional requirements for the remainder of winter. Crude protein concentration in fall-growth vegetation in 1986 exceeded the nutritional requirement for elk maintenance; in fact, crude protein concentrations exceeded maintenance plus lactation requirements.

DMD of bluebunch wheatgrass determined from spring treatments 1 and 2 was similar to crude protein results. In 1986, it exceeded the minimum values (50 percent DMD) for elk as suggested by Ammann (1973) and Hobbs et al. (1981). However, the mature vegetation from 1986 and all spring treatments in 1987 were below DMD rates suggested for elk maintenance. The 1986 fall-growth vegetation, with 70+ percent DMD, again surpassed minimum values prescribed for elk maintenance.

The minimum digestible energy (DE) requirement for free-ranging sheep and cattle is estimated at 1.83 Mcal/Kg DM (Cook and Harris 1950). Elk energy requirements should be very similar to these values (Westenskow 1991). Using Schommer's (1978) equation for converting DMD to DE indicated that minimum dietary requirements for elk were exceeded with the spring-treatment vegetation following fall precipitation in 1986. However, vegetation not clipped and the 1987 data results indicated they were DE deficient.

Anderson and Scherzinger's (1975) conclusions about improving nutrient content of spring-conditioned vegetation were correct. However, even with the conditioned vegetation having increased nutritional values over vegetation not treated, bluebunch wheatgrass failed to meet dietary requirements for elk -- especially when summer or fall precipitation was negligible.

Anderson and Scherzinger (1975) reported elk population increases (from 320 to 1191) on the Bridge Creek winter range area after livestock grazing was initiated. Nutrient content results from my research do not definitively support the Anderson and Scherzinger (1975) hypothesis. The fact is, however, they reported a significant increase in elk use on the winter range area following implementation of cattle grazing and these results should not be disregarded. Numerous variables that could be responsible for increased elk use include palatability of plants, plant preference, previous feeding habits, plant morphology and availability. Any or all combinations of these factors could be influencing the positive elk response to cattle grazing within the area.

Also, other environmental factors such as topography, cover and seclusion may have been more beneficial to winter range conditions for elk than improved forage quality. They mentioned that at the same time the livestock grazing program was implemented, a motorized vehicle restriction was applied to the area during the winter months. However, they did not present data to support their statements. They theorized that by grazing cattle through the area in the spring while soil moisture was still available, growth would occur following the treatment and be higher in nutrient content than ungrazed plant material.

Part of their reasoning was that plants would not be producing a flowering stock and, hence, would maintain higher concentration of nutrients within the leafy material. Pitt (1986) tested this hypothesis and found the nutritional quality of bluebunch wheatgrass could be improved by such treatments. In fact, Pitt (1986) found that the later in the growing season that plants were conditioned (up to the phenological seed formation stage), there was increased crude protein concentration and decreased ADF concentration. However, authors of both papers cautioned that conditioning (grazing) plants at these phenological development stages can increase plant mortality.

Stoddart (1946) reported a 50-55 percent mortality on plants clipped to a 2.5 cm stubble height during the phenological stages of boot to seed formation (mid-May to mid-June). McLean and Wikeem (1985) reported a 92 percent mortality on plants defoliated weekly to 5 cm height throughout the grazing season. Therefore, the trade-off and risk associated with spring conditioning bluebunch wheatgrass to optimize forage quality in the fall may not be in the best interest for improving or maintaining over-all range conditions and plant health.

Plant leaf material has been reported to be higher in nutrient content than other morphological appendages (Skovlin 1967, Holechek et al. 1989). Although no data were found in the literature to support these observations, especially on cured vegetation, the data from this study indicate those observations are valid. The younger the plant material, the higher the crude protein and dry matter digestibility. In both years (1986-87) the third leaf, which was the youngest plant material, had the highest concentration of crude protein and highest DMD value. Although these values were below suggested nutritional requirements for elk, if animals selected the third leaf, or younger if available, they would come closer to meeting dietary maintenance requirements than by consuming whole plants. Bell (1971) and Vavra et al. (1989) suggest when quality is limiting the roughage feeders (i.e., cattle) would be favored and when quantity is limiting select feeders (i.e., deer) would be favored. This hypothesis is primarily based on rumen size -- i.e., body size ratio significantly affects digestibility rates.

On these study areas quantity of forage was not limiting until snow accumulated in mid-to late December of both years and existed through the following February preventing foraging of some plants. Quality of forage based on crude protein and DMD was excellent for fall growth of bluebunch wheatgrass in 1986. However, because of only a measurable trace of precipitation (Table 5) in 1987, no fall growth occurred that year. Westenskow (1991) reported similar results during the two years immediately following this study. Hence, two out of four years quality was limiting due to low precipitation (Table 5) which agrees with Skovlin's (1967) results.

Fall Growth

Translocation of carbohydrates and energy expenditure within plants to produce fall growth is not mentioned in the literature. This void in the literature may be because of variability in quantities of fall-growth production between years. However, fall growth could be valued as a dietary supplement during the years it occurs. Or, it has not been considered to have made a significant contribution to livestock production as most such animals have been removed from public rangelands by this time.

Regardless of why it has not been evaluated, when fall growth occurs it does provide crude protein and DMD nutrient values in excess of nutritional needs for body maintenance of wild ruminants. However, management for optimum fall growth can be enhanced by fall (September, early October) grazing to remove cured vegetation, provided 6-8 cm of precipitation occurs simultaneously. Although amounts of carbohydrate reserves utilized by bluebunch wheatgrass for fall-growth production and translocation of carbohydrates to root reserves have not been documented, it seems likely that this would be advantageous by having leaf material present for photosynthesis to occur for plants the following spring during the years fall growth does occur (Willms et al. 1980).

Primarily from an interspecific-plant competition standpoint, the fall-growth material can begin photosynthesis production earlier the following spring and begin utilizing soil nutrients and moisture competitively with annuals and/or other perennial plants (Mueggler 1972). Nowak and Caldwell (1984) reported fall growth ceases growth during the winter but will resume growth the following spring.

I think that early grazing the spring following fall growth would retard the competitive edge bluebunch wheatgrass has on other plant species, especially introduced annuals. Data from this study supports Nowak and Caldwell's (1984) conclusions that plants retard growth sometime in November or early December and resume growth when conditions prevail during the spring. In fact, there was some growth occurring under the snow during the fall of 1986. The quality of fall growth exceeded the crude protein (5.7 percent) and DMD (50 percent) values which have been suggested as minimum for elk maintenance requirements (Nelson and Leege 1982, Hobbs et al. 1981, Ammann 1973).

Over-Winter Effect on Nutrient Content

Freezing and thawing of fall growth from bluebunch wheatgrass had little (25 percent) effect on crude protein concentration and no effect on DMD. Percent crude protein for fall growth started above 20 percent in October and only dropped down to 15 percent by March the following year. DMD started at 80 percent and remained close to this value throughout the winter months.

Although there was a significant difference in crude protein between fall and spring values it retained values above suggested dietary requirements for elk. Apparently the freezing, thawing and potential leaching from winter weather conditions were not severe enough to retard nutrient content as moisture stress and temperature do during the summer months (Blaisdell 1958). Either the high moisture content during the fall and winter months maintains sugar concentration, or freezing prevents translocation of carbohydrates back to root reserves. During extremely cold periods the plants maintained plasticity and would not break when folded.

I believe the sugar concentration within the leaf material must be such that it prevents freezing and bursting of cells. On the other hand, cell walls may be flexible enough to prevent the cells from breaking.

These results from over-wintering vegetation might provide a clue to why summer-cured plants lose nutrient content throughout the summer months. Translocation of carbohydrates from summer growth may continue back to root reserves long after the time it was thought to cease (Allayne-Chan 1986). The percent crude protein from summer cured plant tissue (Treatment 5) declined (8 percent in 1986 and 19 percent in 1987) throughout the winter months. Leaching could explain why crude protein was lost from the plants exposed to the snow pack.

However, plants within the snow shelters which were exposed to freezing and thawing but had no contact with snow responded similarly. These crude protein values were low (3.0-3.5 percent) and continued to decline. The quality of winter forage resulting from summer-cured vegetation declined during a time when wintering big game populations are depleting body reserves and could desperately need high quality forage to compensate.

Available Forage

Dragt and Havstad (1987) working in Montana reported grazing of the different phenological stages of bluebunch wheatgrass did not affect winter forage quality as measured in crude protein or carbohydrates. They also suggested quantity of available forage was more important than quality on Montana winter ranges. Westenskow (1991) reported a decrease of 33 percent in 1988 and 47 percent in 1989 in production of bluebunch wheatgrass from plants conditioned in spring versus vegetation not conditioned. Furthermore, fall defoliation of bluebunch wheatgrass through clipping decreased available forage by 95 percent in 1988 and 81 percent in 1989.

In 1987, there was a 25 percent difference between the plants clipped in spring and plants not clipped. Both defoliation treatments (1 and 2) carried out in the spring produced the same amount of spring-/summer-growth herbage. These differences are similar to those reported by Westenskow (1991). Plants clipped in September (Treatment 3) produced 22.4 Kg/ha DM of fall growth compared to production of 219 Kg/ha DM from plants not clipped, representing a 90 percent difference in available forage. The least amount of fall growth was produced by plants clipped to 2.5 cm in the spring (Treatment 1). A 50 percent difference between treatment

1 and treatment 3 and a 95 percent difference between annual production and fall growth occurred.

Quality and quantity with respect to availability are significant factors for range managers to consider. Quality can be significantly enhanced at the cost of quantity but if snow pack prevents grazers from reaching that forage quantity may be more important. Westenskow (1991) presented data that illustrated the quality of fall growth, when it occurred, exceeded the dietary energy requirements for a 230 Kg cow elk. In comparing Westenskow's data on digestible energy (DE), data reported here supports her observations.

However, the majority of fall growth of bluebunch wheatgrass from all three study sites was not available to wintering big game animals for 60-75 days during both years of the study because of snow. Although elk can paw through snow to obtain forage, significant energy can be expended. The snow pack in the Blue Mountains commonly goes through several stages. Early snows usually have a high moisture content and can be removed by pawing quite easily. However, because of temperature fluctuations (-28°C to 0°C), the snow often begins to melt and then refreezes creating multiple layers of ice. These sheets of ice can be 20-30 cm thick, creating an impediment for elk trying to paw through it to forage. Similar events occur on slopes with southern aspect, but the duration of this condition is usually curtailed by solar radiation (Leege and Hickey 1977, Robinette et al. 1952).

SUMMARY AND CONCLUSIONS

The objective of this research was to evaluate the Anderson and Scherzinger (1975) hypothesis that grazing bluebunch wheatgrass during the late spring and early summer would provide quality forage for wintering elk. Simultaneously, I wanted to evaluate the different growth stages of bluebunch wheatgrass to establish which growth stage would provide the highest quality forage during the winter months for elk.

Three study sites were located on known elk winter ranges that supported bluebunch wheatgrass plant communities. All three study sites were in the same general area close to the Starkey Experimental Forest and Range in northeastern Oregon.

Two spring treatments (plants clipped to 2.5 cm and 7.6 cm stubble height), one fall treatment (plants clipped to 7.6 cm stubble height) and no treatment were applied to bluebunch wheatgrass plants. Sampling of bluebunch wheatgrass vegetation from treatments occurred monthly from October to April in 1986-87 and 1987-88. Percent crude protein, DMD, ADF and lignin values were used to determine nutrient content and evaluate forage quality of bluebunch wheatgrass.

Plant Appendages

Data on nutrient content of summer-cured plant appendages collected in September of each year indicate there were significant ($P<.05$) differences in percent crude protein, DMD and lignin in the culm, inflorescence and leaf material. Although there were differences between years in nutrient content values the results were similar. The crude protein and DMD values of leaf material were significantly higher than values for the culm and inflorescence plant material in both years.

This would indicate leaf material is of higher quality than the culm and inflorescence. The third leaf (youngest leaf) had the highest percent crude protein and DMD both years followed sequentially by second and first leaves. The highest percent crude protein (4.32 percent in 1986 and 4.3 percent in 1987) of third-leaf plant material collected following summer senescing is less than the 5.7 percent crude protein required for elk maintenance by Nelson and Leege (1982). All DMD values (46.16 percent in 1986 and 43.58 percent in 1987) from the plant appendages collected following summer senescing were below the 50 percent DMD suggested as a minimum maintenance requirement for ruminants by Ammann (1973) and Hobbs et al. (1981). These data validate Skovlin's (1967) observation that leaves have higher nutrient content than seed stalks. By selecting plant-leaf material from cured bluebunch wheatgrass plants, deer and elk can improve their diet quality.

Fall Growth

The fall growth of bluebunch wheatgrass provides high quality forage (Miller et al. 1986, Skovlin 1967). However, quantification of bluebunch wheatgrass nutrient content for fall growth has not been documented. Only during the 1986-87 sampling period was there adequate precipitation to promote fall growth. The nutrient quality values of bluebunch wheatgrass fall growth as measured by crude protein, DMD, ADF and lignin from this research indicated a high quality forage.

Crude protein values ranged between 14.14 to 22.84 percent, DMD values ranged between 66.16 to 84.20 percent, ADF values ranged between 16.17 to 32.01 percent and lignin values ranged between 1.08 to 5.34 percent from October 1986 to April 1987. Regardless of treatment, the value of fall-growth plant material was higher in nutrient content than any other plant growth forms measured. These nutrient content values for fall growth exceed the dietary requirements recommended for elk maintenance by Nelson and Leege (1982). The crude protein and DMD values are similar to spring (April-May) growth values of 11.5 to 18.3 percent crude protein and 67.6 to 68.6 percent DMD reported by Svejcar and Vavra (1985).

Quantity of bluebunch wheatgrass fall growth is limited by late summer or early fall precipitation and autumn temperatures. The availability of fall growth to wintering big game populations can be hampered by snow conditions, senescing plant material ("wolf" plants) and competition from livestock grazing. Although fall growth can not be managed because of its relationship to climatic conditions, some winter range management strategies could be implemented to improve forage availability to wintering big game populations. For example, late summer (August/September) grazing by cattle could reduce senescing plant material from plants, increasing availability of fall growth if climatic conditions prevail.

Removing the cattle from winter range areas by the end of September could reduce the potential competition for fall-growth forage between livestock and big game. Also, by grazing these areas with cattle during late summer the potential impacts of inducing plant mortality would be reduced. This would alleviate concerns Anderson and Scherzinger (1975) and Pitt (1986) had about grazing or conditioning bluebunch wheatgrass plants in late spring or early summer when plants are susceptible to defoliation and increased plant mortality occurs.

Spring-Clipping Plants

Bluebunch wheatgrass plants were clipped to 2.5 cm (Treatment 1) and 7.6 cm (Treatment 2) stubble height just before the boot stage in May 1986 and 1987. The plant growth following these treatments was evaluated to determine the nutrient content values of growth following treatment from October to April in 1986-87 and 1987-88. There were significant differences ($P<.05$) between years, therefore, each year was evaluated separately. The 8+ cm of precipitation during August through October 1986 caused a "greening-up" of bluebunch wheatgrass plants.

There were no significant differences in percent crude protein, DMD, ADF and lignin between the two treatments from October 1986 to April 1987. Both crude protein values (14+ percent) and DMD values (69+ percent) were high, which indicate a high quality forage. These values are in excess of dietary nutritional requirements for elk as suggested by Nelson and Leege (1982). I think the 8+ cm of fall precipitation is responsible for the increased crude protein and values over the 4-6 percent crude protein values reported by Skovlin (1967) in October and late July by Svejcar and Vavra (1985).

In 1987-88, without the late summer/early fall precipitation, different results were produced. I also think the effects of spring clipping on nutrient content during the 1987-88 season better illustrate how nutrient contents of plant growth respond to summer temperature and moisture stresses that Anderson and Scherzinger (1975) hypothesized would improve forage quality over plants not treated.

Results indicated there were no differences in percent crude protein between the plants clipped to 7.6 cm stubble height and plants not clipped from October through December, however, in April there was a difference. With the exception of April, the percent crude protein of plants clipped to a 2.5 cm stubble height was significantly different with higher values than both plants not clipped and the other spring-clipped vegetation.

Crude protein values from the three treatments ranged from 3.32 to 5.73 (Treatment 1) from October 1987 to March 1988. In April, the crude protein values increased to 18+ percent for all treatments except for plants not clipped (Treatment 5), and that value decreased. The percent DMD, ADF and lignin values responded similarly.

DMD values for treatment 1 ranged from a high of 44.47 percent (Treatment 1) in October to a low of 31.64 percent in March. The treatment 5 (plants not clipped) values ranged from a high in October of 37.38 percent to a low of 22.73 percent in March. In

December, there was no significant difference in DMD between the three treatments.

Although statistical differences existed ($P<.05$) in nutrient content as measured in crude protein, DMD, ADF and lignin growth from plants clipped and not clipped during some months, there were other months where no significant difference ($P>.05$) existed. The alternate hypothesis was accepted because a significant difference existed between treatments in nutrient content values. However, the spread between crude protein values was less than 2 percent and 10.5 percent in DMD values. In evaluating the data I do not think there is a definitive improvement in forage quality of spring-/ summer-plant growth vegetation from spring clipping before the boot stage. In addition to not appreciably improving the forage quality of spring/summer plant growth, the risk of increasing plant mortality with spring grazing needs to be considered.

The nutrient content of plant growth from these three treatments, except crude protein (5.7 percent) of treatment 1 in October, did not meet the dietary requirements recommended for elk maintenance any month through the winter as described by Nelson and Leege (1982).

Plant Production

Production of fall growth is dependent on late summer and early fall precipitation and warm temperatures. Therefore, production of fall growth only occurred in 1986. The production of fall growth from treatment 1 (plants clipped to a 2.5 cm stubble height) had only about 50 percent (11.2 Kg/ha to 22.03 Kg/ha) of the production of treatments 2 and 3. This same pattern existed from production within the snow shelters, where production was 24.12 Kg/ha for treatment 1 and 50.4 Kg/ha and 78.6 Kg/ha for plants from treatments 2 and 3 respectively. This quantity of fall-growth production could benefit big game populations by minimizing the amount of time spent foraging to meet their dietary requirement.

Production of treatments 1 and 2 (plants clipped in the spring) produced the same amount of forage in October of 1987. This represented about 76 percent of current-year's production of bluebunch wheatgrass.

Freezing and Thawing

Nutrient content of bluebunch wheatgrass fall-growth vegetation which was exposed to freezing and thawing compared to fall-growth vegetation under snow was not appreciably different. Crude protein values for fall-growth vegetation exposed to 3 months of freezing and thawing had crude protein and DMD of 19.91 percent and 79.67 percent respectively. Fall-growth vegetation which had been under snow had crude protein and DMD values of 19.26 percent and 80.48 respectively. However inconsequential this may be to dietary requirements for elk, it does provide insight to what effects freezing and thawing have on nutrient content of bluebunch wheatgrass. On snow-free south-facing slopes where big game populations congregate, nutrient content in plants that are exposed to freezing and thawing daily does not decline due to the freezing and thawing condition.

Conclusions

Parameters of elk winter range areas are complex, variable and interwoven. No single isomorphic entity can fully describe these interactions. Winter severity -- primarily snow depth -- has more influence on availability of winter range areas than most other attributes, although forest cover, topographic relief, and availability of forage are important winter range features. When the accumulation of snow increases then vertical movements are restricted and the size of winter range areas decreases. Thus, elk are forced into limited space, intraspecific competition for forage may occur and potential conflicts develop with private-land managers for available forage resources.

The foraging behavior of elk is also a complex interaction of several variables. The animal's physiological condition, digestion rate, and availability, palatability, quantity and quality of forage are all important nutritional facets. Defining quantity and quality parameters within elk daily dietary requirements can only be postulated. However, successful management practices which can enhance forage availability, quantity and quality for improvements in required dietary nutritional energy for wintering elk on fall/winter range areas can be achieved. Although forage availability can be influenced by snow accumulation, the quantity and quality can be improved when fall growth is available.

The results of this study indicate the stages of plant growth from bluebunch wheatgrass which provide quality forage for wintering elk. Although the results are limited, I think useful information can be extracted by the land manager to provide or improve winter range forage conditions on grassland ecosystems for big game populations. Additional research on other winter range attributes is needed to help understand the complexity of winter range interactions.

RECOMMENDATIONS

Definitive recommendations for all aspects of these data are difficult to generate because of variability between years due to precipitation. However, I think forage quality parameters of nutrient contents in plant appendages and summer-cured vegetation provide conclusive data.

Depending on primary land management objectives, limiting factors and ecological status of the winter range areas, both public and private resource managers need to evaluate their goals before implementing management plans. On public lands delineated as big game winter range with the emphasis to provide optimum forage quality, the public-land manager needs to address both the Multiple Use-Sustained Yield Act of 1960 and Resources Planning Act of 1974.

If the primary goals of either public or private winter range area managers are to provide optimum forage quality for wintering big game populations and to maintain or improve ecological status of the rangeland while minimizing the impacts on bluebunch wheatgrass, then the following recommendations might be considered.

1. Livestock should be removed from bluebunch wheatgrass winter range areas by mid- to late September each year. This would minimize competition between livestock and big game populations for fall-plant growth, reduce the chances of adverse impacts from concentrated livestock numbers on plant health and maximize production of high quality fall-growth vegetation for

big game use during the years when climatic conditions are sufficient to promote fall-plant growth.

2. Since the nutrient content of summer-cured bluebunch wheatgrass does not meet the minimum dietary maintenance requirements for elk, bluebunch wheatgrass can be grazed to a 7.6 cm stubble height after seed formation. This can reduce plant mortality and increase the production and availability of fall-plant growth during the years when fall precipitation and temperatures prevail to stimulate fall growth.

3. Elk and deer winter range areas should be delineated and livestock grazing strategies implemented on those ranges to provide optimal forage quality for wintering deer and elk.

4. Big game populations should be regulated to less than the traditional winter range carrying capacity so habitat degredation is prevented.

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APPENDIX

APPENDIX 1

Anatone

(Extremely Stony Loam, 2 to 35 Percent Slopes)

This shallow, well drained soil is on ridgetops and on south- and west-facing side slopes of uplands. It formed in colluvium and residuum derived dominantly from basalt. Some loess and volcanic ash is in the surface layer. Elevation is 3,500 to 5,000 feet. The average annual precipitation is about 17 to 30 inches, the average annual air temperature is 43 to 45 degrees F, and the average frost-free period is 90 to 130 days.

Typically, the surface layer is dark brown extremely stony loam about 6 inches thick. The subsoil is dark brown very cobbly loam about 5 inches thick. Below this is basalt that is fractured in the upper 5 inches. Depth to basalt ranges from 10-20 inches.

Included in this unit are small areas of Klicker and Bocker soils and Rock outcrop. Included areas make up about 20 percent of the total acreage.

Permeability of this Anatone soil is moderate. Available water capacity is about 1 inch to 2.5 inches. Water supplying capacity is 5 to 10 inches. Effective rooting depth is 10 to 20 inches. Runoff is slow to rapid, and the hazard of water erosion is slight to high.

This unit is used as rangeland and for wildlife habitat.

The potential plant community on this unit is mainly bluebunch wheatgrass, Idaho fescue, and stiff sagebrush. The production of vegetation suitable for livestock grazing is limited by the shallow depth to bedrock and droughtiness. If the range is overgrazed, the proportion of preferred forage plants decreases and the proportion

This unit is about 50 percent Anatone extremely stony loam and about 40 percent Bocker very cobbly silt loam. The components of this unit are so intricately intermingled that it was not practical to map them separately at the scale used.

Included in this unit are small areas of Rock outcrop and Royst soils.

The Anatone soil is shallow and well drained. It formed in residuum and colluvium derived dominantly from basalt. Some loess and volcanic ash is in the surface layer. Typically, the surface layer is dark brown extremely stony loam and 6 inches thick. The subsoil is dark brown very cobbly loam about 5 inches thick. Below this is basalt that is fractured in the upper 5 inches. Depth to basalt ranges from 10 to 20 inches.

Permeability of the Anatone soil is moderate. Available water capacity is about 1 inch to 2.5 inches. Water supplying capacity is 5 to 10 inches. Effective rooting depth is 10 to 20 inches. Runoff is slow to medium, and the hazard of water erosion is slight to moderate.

The Bocker soil is very shallow and well drained. It formed in residuum and colluvium derived dominantly from basalt. Some loess and volcanic ash is in the surface layer. Typically, the surface layer is dark reddish brown very cobbly silt loam about 2 inches thick. The subsoil is dark reddish brown very gravelly loam about 5 inches thick. Fractured basalt is at a depth of 7 inches. Depth to basalt ranges from 4 to 10 inches. Permeability of the Bocker soil is moderate. Available water capacity is about 0.5 to 1 inch. Water supplying capacity is 2 to 5 inches. Effective rooting depth is 4 to 10 inches. Runoff is slow to medium, and the hazard of water erosion is slight to moderate.

This unit is used as rangeland and for wildlife habitat.

The potential plant community on this unit is mainly bluebunch wheatgrass, Idaho fescue, Sandberg bluegrass, and stiff sagebrush. The production of vegetation suitable for livestock grazing is limited by depth to rock and low available water capacity. If the range is overgrazed, the proportion of preferred forage plants decreases and the proportion of less preferred forage plants increases. Therefore, livestock grazing should be managed so that the desired balance of species is maintained in the plant community.

The suitability of this unit for rangeland seedling is poor. The main limitations for seedbed preparation and seeding are the depth to rock and the extremely stony and very cobbly surface layer.

Use of mechanical treatment practices on this unit is not practical, because the surface is stony and the slopes in some areas are steep. Management practices suitable for use on this unit are proper range use, deferred grazing, rotation grazing, and aerial spraying for brush management. Livestock grazing should be managed to protect the unit from excessive erosion. Loss of the surface layer results in a severe decrease in productivity and in the potential of the unit to produce vegetation suitable for grazing.

This unit is poorly suited to homesite and recreational development. The main limitations are stoniness and depth to bedrock.

This map unit is in capability subclass VIIs, nonirrigated.